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IRRIGATION AND SOIL CONDITIONS IN THE SIERRA NEVADA FOOTHILLS, CALIFORNIA

BY

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(Based on work done under co-operative agreements between the Office of Experiment Stations and the State Engineering Department of California, and between the Office of Experiment Stations and the California Agricultural Experiment Station.)

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CONTENTS

ILLUSTRATIONS

IRRIGATION AND SOIL CONDITIONS IN THE SIERRA NEVADA FOOTHILLS, CALIFORNIA

BY

RALPH D. ROBERTSON AND J. W. NELSON*

INTRODUCTION

The purpose of this report is to show the present status and the possibilities of irrigation in the foothills along the western slope of the Sierra Nevada, California, to describe, in general, the soils of this region, and to discuss the adaptation of these soils to various crops. The intent is thus to furnish information on the agricultural resources of the various sections covered.

Irrigation development in this part of California has been comparatively slow, and yet many of the same agricultural and horticultural opportunities are offered there that are offered in the valleys below. The relatively slow development in these foothills has been due principally to the lack of transportation facilities and to the more general interest there in mining than in farming. As long as gold could be washed from the soil, little attention was paid to the money that could be made by the slower processes of agriculture.

The Sierra foothills possess extremely favorable conditions for growing certain crops and the time may soon come when this belt of elevated land will become one of the most important agricultural districts in California. Every agricultural product that can be grown in the great central plain can also be produced here. The chief production is likely, however, to be confined to deciduous and citrus orchards and to vineyards.

The climate of these foothills is somewhat similar to that of the central valley, but the greater freedom from frost possessed by the so-called foothill thermal belt is a distinct horticultural advantage.

* In the preparation of the report Mr. Robertson has given particular attention to matters of irrigation practice and possibilities and Professor Nelson has given particular attention to matters of soils and crop adaptation.

The expense of the investigation, in so far as it related to irrigation, has been met from funds contributed by the Office of Experiment Stations and the California State Department of Engineering. The expense, in so far as the investigation related to soils and crops, has been paid by the California Agricultural Experiment Station. Neither party assumes any responsibility for the parts prepared by the representative of the other party.

Water for irrigation is available for much of the land from numerous streams and reservoirs. The soils are generally fertile and particularly adapted to the growing of fruit and certain sections have made rapid progress. Tulare County, the citrus orchards of which are largely in the foothill belt, now ranks first among the counties of the State in acreage planted to oranges. Placer County, farther north, is taking a leading place among the deciduous fruit districts, its shipments of fresh or "green" fruit recently amounting to about 35 per cent of the total output of the State. The success that has been obtained in these two sections can be, and in more or less measure is being accomplished in other localities of the region.

Irrigation in the Sierra foothills is not accomplished without some difficulty. Topographical features require methods of irrigation essentially different from those used in the valleys. Consequently information about the methods that have been worked out there, and that are described in this report, should be of value to other localities similarly situated.

GENERAL DESCRIPTION

The Sierra foothills of California comprise a belt of land on the western slope of the Sierra Nevada extending from Tehachapi, at the southern end of San Joaquin Valley, to Redding, at the head of Sacramento Valley, a distance of approximately 400 miles. The average breadth of the belt is about 20 miles, and within this territory are included approximately 5,000,000 acres, or 5 per cent of the total land surface of the State. The arable portion of the foothills comprises from about ⅓ to about ⅗ of the total area, depending on the portion of the 1,400,000 acres sometimes classed as "plains" that are included with the higher areas lying above them.[1] Above the San Joaquin Valley the foothills rise abruptly, first with low broken ranges and spurs, interspersed with isolated hills and small valleys, then followed by ranges of gradually increasing height. In the foothills bordering the Sacramento Valley the rise is more gradual. The general topography consists of deeply dissected canyons, rugged, rocky ridges,

[1] The term "foothill" as used in this report is intended to cover the area extending from the main floor of Sacramento and San Joaquin Valleys up to elevations of about 3000 feet. The higher east side areas of the valleys that are generally classed as "plains" are therefore, to a considerable extent, especially in Tulare County, considered as embraced within the "foothill" belt. For a more restricted classification of Sierra foothills, embracing 1,519,000 acres of arable land, see U. S. Dept. Agr., Office Expt. Sta. Bull. 254, pp. 19 and 28.

slopes, rounded hills of gentle to moderate contour, and small, narrow, winding valleys. In many sections of the foothill region the land is covered with a coarse growth of chapparal, scrub oak, and "digger" or gray leaf pine. Large areas, again, are barren of trees, and in these, owing to the shallowness of the soil and to the stony character of the surface, the land is useful only for grazing. In the northern and central portions there are visible signs of former volcanic activity. Lava beds cover nearly the entire country north of Feather River, and a heavy flow of lava can also be traced as far south as Tuolumne County.

The principal irrigation development of the foothill belt is found in three sections, namely, in the Tulare and Fresno Counties citrus belt, in the Placer County deciduous fruit belt, and in the vicinity of Oroville, in Butte County. Because development has gone farthest in these three sections, irrigation conditions in them are described more in detail than are those of the other districts of the foothills. While in this report an altitude of 2500 to 3000 feet is taken as the upper limit of the foothills, the apple flourishes in the higher altitudes and hardier deciduous fruits may be grown up to a height of at least 4000 feet. Stock raising is generally practiced in these higher altitudes, and the mountains afford summer grazing for thousands of cattle and sheep from the valleys.

The Sierra foothills have been mainly known for their early mining activities. The fact has an important bearing on irrigation there because the ditches now used for irrigation were originally constructed for mining purposes. The eager gold seekers were early confronted with the problem of securing an adequate water supply for carrying on their mining operations, because for hydraulic mining, water was needed in large and unfailing quantities. In this rough and broken country many engineering difficulties were encountered in the construction of ditches, and because of this, and the high cost of labor, the ditches now in use for irrigation represent a very large original investment. After the exhaustion of the richer gold deposits and the passage of laws prohibiting hydraulic mining, many of the residents turned their attention to agriculture, taking water from the old mining ditches and irrigating small vegetable gardens and orchards. These people demonstrated the success of fruit growing in these foothills, but the isolation of the region and the long haul to railroad points in early days confined the growing of crops to a home supply. While mining is still an important industry in the Sierra foothills, the agriculture that irrigation makes possible is recognized as the industry that will endure and give the region its permanent character.

CLIMATE

The climate of the foothills up to an altitude of about 1500 feet is quite like that of the central valley of California, with the exception that winter fogs are of rare occurrence. The summers are hot and dry, with cool nights, the rainfall occuring from about the first of November to April. The winters are mild and equable. The rainfall increases with the altitude and, in general, this increase has been found to amount to from about 0.60 to about 0.84 inch in each 100 feet elevation, up to about 6000 feet.[2] Above this, and up to about 9000 feet, the rate of increase is somewhat less.

Between elevations of about 200 and 1200 feet above sea level, this region has earned for itself the designation "Thermal Belt." This is because the area in this belt is less subject to frosts than lower lying bodies of land in the valley floor. This thermal belt is continuous along the foothills, but its precise boundaries depend upon local topographical features. Professor Wickson has called attention to the fact that in many of the small valleys among the foothills, both of the Sierra Nevada and the Coast Range, frosts may be more severe than on the hills adjacent or in the broader valleys to which they are tributary. It is known that cold air has a tendency to settle in low places while the warm air rises to higher levels. For this reason slopes and rounded hills are often more desirable for growing fruit trees than small valleys that may appear to be well protected. Oranges are grown with equal success in the hills east of Bakersfield and at Oroville 300 miles north, ripening several weeks earlier in these sections than in southern California. This early ripening in the foothills is ascribed to the presence on the west of the Coast Range, which acts as a barrier against the cool winds from the ocean and hastens springtime and summer heat. Besides, the orchard sections of the Sierra foothills are sufficiently distant from the snows of the higher elevations to enable the cold air currents descending from the mountains to be warmed before reaching them.

The mean monthly and annual precipitation and temperatures at different stations in the Sierra foothills are given in the following tables compiled from the records of the United States Weather Bureau:[3]

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[2] U. S. Geol. Survey, Water Supply and Irrig. Paper, No. 81.

[3] U. S. Dept. Agr., Weather Bureau Annual Summary, 1913.

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN THE SIERRA FOOTHILLS

Station	Elevation	Years record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Porterville	464	25	1.85	1.62	1.85	.79	.71	.11	.01	.01	.29	.52	.76	1.49	10.02
Jamestown	1471	11	8.90	5.01	8.21	2.22	1.47	.24	.00	.00	.64	1.18	1.92	4.14	33.93
Mokelumne Hill	1550	21	5.40	4.93	6.24	2.79	1.57	.41	.00	.02	.59	1.64	3.72	5.24	32.55
Oroville	250	30	5.48	4.33	4.20	1.98	1.46	.33	.02	.02	.71	1.62	3.47	4.78	28.40
Placerville	1875	37	8.23	6.31	7.86	4.25	2.19	.66	.02	.03	.72	2.29	4.84	7.22	44.62
Auburn	1360	43	6.51	5.58	5.72	3.02	1.52	.44	.01	.02	.53	1.94	3.92	5.92	35.13
Nevada City	2580	43	10.60	8.19	8.93	4.50	2.39	.67	.02	.05	.77	2.62	6.19	10.39	55.32
Redding	552	39	7.77	5.57	5.38	2.96	2.24	.73	.09	.07	.78	2.42	4.17	6.54	38.72

MEAN MONTHLY AND ANNUAL TEMPERATURES AT STATIONS IN THE SIERRA FOOTHILLS

Station	Elevation	Years record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Porterville	464	25	48.0	51.8	56.2	62.9	70.3	78.8	84.8	82.6	75.1	64.9	54.9	47.8	64.8
Jamestown	1471	11	45.?	47.5	50.8	55.7	60.0	68.2	75.3	73.9	68.2	59.9	50.9	43.7	58.3
Mokelumne Hill	1550	21	43.6	46.8	48.6	54.7	58.8	68.1	76.8	74.2	67.8	60.3	51.8	44.2	58.0
Oroville	250	30	46.8	50.6	54.3	59.5	66.1	74.5	80.2	78.6	73.0	65.4	55.9	47.8	62.8
Placerville	1875	25	41.6	44.3	47.4	52.2	58.0	66.4	72.6	69.9	63.5	56.3	48.1	42.4	55.2
Auburn	1360	43	45.6	48.1	51.7	56.5	62.7	70.8	76.8	75.9	71.0	64.6	55.0	47.0	60.5
Nevada City	2580	22	41.5	43.1	44.8	50.5	55.6	62.7	68.8	68.1	62.2	55.7	47.8	42.4	53.6
Redding	552	39	45.2	49.3	53.8	60.2	67.2	75.6	82.3	81.0	74.0	64.5	54.1	47.0	62.9

SOILS AND AGRICULTURE

The soils of the Sierra foothills have in most cases been formed from granitic and metamorphic rocks. In the lower foothills and in local small valleys, minor deposits of sedimentary and alluvial material have accumulated but they are of minor importance in this belt. In the northern half of the belt the rocks are mainly basic in character and in their weathering have formed gently rounded hills and slopes, while in the south half of the Sierras, the higher slopes are largely of granitic rocks and have weathered into a steep, rugged topography permitting of agriculture only in the lower foothills. The soils vary greatly in color, depth, texture, and composition on account of the complexity of geological formations and climatic influences entering into their formation.

The disintegration and weathering of rocks have proceeded under climatic conditions ranging from arid to humid. This has had a marked effect upon the soils at different elevations. The soil-forming processes in the lower foothills have gone on with a low to moderate rainfall, while those in the higher elevations have taken place with an annual precipitation of 40 to 50 or more inches. The heavy rainfall of the higher elevations has clothed the mountains with a dense covering of pine, underbrush, and grass, while the drier conditions at lower altitudes have usually permitted of only a sparse growth of pine, oak, and grass and a rather heavy covering of brush. In places of heavy rainfall, moisture has passed downward in crevices, joints, and parting planes, and has frequently caused a deep weathering of the underlying rocks. The heavy growth of vegetation in such places has checked erosion considerably and has stimulated the formation and accumulation of humus in the soil, thus making possible the retention of more moisture for the dry summer months. The lower humus content and sparser vegetative covering of the lower foothills have not checked erosion so much and in many places the soil has been moved to lower levels almost as rapidly as it has accumulated.

The soils over the entire belt are relatively high in iron and are prevailingly red in color, although areas of gray, brown, and black occur. A few minor areas of sandy loam occur on the higher residual slopes and marginal areas along the valley floor. Elsewhere, the prevailing textures are loams and clay loams. Small isolated areas of dark brown to black adobe occur on the slopes in the lower foothills.

About half of the area covered by this report is too steep and rocky for the growing of crops. On the more gentle slopes and where the rocks are weakly cemented the soil covering is deeper and ranges from

1 foot to 6 feet or more in depth. In many instances the soil rests on upturned rocks which are creviced and seamed to considerable depths. These crevices have been filled by the filtering down of disintegrating soil material, and in many places tree roots develop downward in such cracks 20 or more feet. Frequently, where shallow soils rest upon upturned rocks or on partially weathered granite, blasting is followed with much success in extending the area for root development. Where the rock occupies a nearly horizontal position and is hard, this practice is not advisable because of inadequate drainage in the bowls where the trees are set.

The soils generally have a friable, mealy texture when damp and are tilled without difficulty. In areas of granitic origin and especially where moderate amounts of coarse sand and gravel are present, the soils tend to pack when dry and are rather difficult to till at such times.

The soil is generally uniform in character down to the underlying bed rock and no true subsoil nor hardpan is present except along the margin of the valley floor. In granitic areas, where the rainfall is moderate to low, disintegration and water movement are causing the formation of subsoils of heavy texture at various depths which will in the course of time cement into a hardpan. This feature becomes more pronounced as the base of the foothills is approached. A pronounced indurated hardpan occurs from a few inches to several feet below the surface of the red hog-wallow foothill lands along the margin of the great valley floor. Elsewhere no obstructions occur in the soil which interfere with tillage or root development.

The topography and drainage of the foothills are not favorable in most places for the development of a high water table or for the accumulation of alkali. In highly developed areas where irrigation is practiced and especially where water is sold at a flat rate, some injury from seepage is occurring in the small valleys and on lower slopes. No pronounced areas of alkali have formed in such places as yet, but conditions are very favorable for its accumulation unless preventive measures are soon taken. Occasional areas along the valley margin which are now poorly drained, or which have received seepage waters from higher eleevations in past times, are affected with injurious amounts of alkali. Practically all of the affected areas, however, have ample slope for successful reclamation.

The humus content of the soils of the foothills is relatively low, but usually increases with elevation, due to the higher rainfall and increased growth of vegetation.

The marked variation in elevation, rainfall, temperatures, and soils makes a wide range of profitable crops possible in this belt. The

lower altitudes are generally too hot for commercial apple production, but elevations above 1800 feet give fruit of remarkably fine flavor, color, and keeping qualities. The sandy loams, loams, and clay loams for apples and pears appear to give the best results in this belt. Pears are frequently planted and do well on the lower slopes and in small valleys too wet for other fruits. The sandy loams and light loams of granitic origin produce pears, plums, cherries, apricots, figs, and grapes of high quality, color, and earliness. Heavy textured soils are usually the most durable. They do not warm up rapidly in spring, but usually give the largest yields and longest lived trees.

Citrus fruits, especially oranges, are grown successfully throughout the entire length of the belt. They thrive on a wide range of soils, but the best results are obtained where the trees are planted on loams and clay loam adobes below the 1200-foot contour. Little commercial fertilizer is used in most places and fruit trees have been maintained profitably for 20 years or more with only the addition of green manure crops and with good tillage and care. The long growing season and high summer temperature permit of a wide range of cover crops which, if fully utilized, will enable farmers to secure increased yields without much additional cost.

The influence of the high summer heat has a marked effect upon different exposures over the entire foothill belt. The soils on the northern and eastern slopes in nearly all places contain more humus, support a denser vegetation, retain moisture longer, and are generally considered more suitable for fruit culture than those with a western or southern exposure.

The abundance and thrift of native vegetation over the entire belt is a fair indication of the depth, fertility, and moisture-retaining properties of the soil.

WATER SUPPLY

The streams having their source in the Sierra Nevada and which flow into the San Joaquin and Sacramento Rivers, constitute the available water supply for the lower foothills, as well as for the valley floor. Where the present surface supply is utilized in the valleys, storage will be necessary for the fullest development of the foothills. Underground waters are being utilized in some sections and constitute an important factor in irrigation development. The divides between the basins of the individual rivers are rough and irregular in outline and may be likened in shape to a fan, the broad part being along or near the

crest of the mountains, and the apex at the point where the channel meets the valley. Between these main streams smaller creeks take the run-off of the lower ranges and foothills; their flow is torrential and intermittent during the rainy season, and after reaching the plains their waters spread out and are eventually lost in the sandy soil.

The principal rivers furnishing water for irrigation from south to north are as follows:[4]

Above San Joaquin Valley: Kern, Tule, Kaweah, Kings, San Joaquin, Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes Rivers.

Above Sacramento Valley: American, Bear, Yuba, Feather, and Sacramento Rivers.

THE USE OF SMALL WATER SUPPLIES

Throughout the Sierra foothills there are numerous springs which may be made to yield a large revenue if the flow from them is stored in small reservoirs. The majority of springs may be too small to use the flow continuously, but when it is allowed to accumulate for a few days or a week in a reservoir it is capable of irrigating a considerable area. It might be considered a waste of time and water to supply a flow of one miner's inch directly to the soil, yet such a flow with proper storage might serve several acres of highly valuable land. One irrigator in Eldorado County irrigated successfully 2 acres from a small spring having a flow of only about 1 inch. The discharge of the spring was stored in an earthen reservoir 100 feet long, 60 feet wide, and 3½ feet deep, holding about one half of an acre-foot of water. This small flow produced in one season fruits and vegetables having a value of $400. This illustrates how a small spring may be utilized to good advantage. Usually all of the work connected with building such a reservoir can be done by the farmer and the only outlay is for material which is small.

Small reservoirs may likewise be used to good advantage in storing the storm waters of small creeks or torrential streams which flow during the winter months and have dry beds during the summer. There are numerous small reservoir sites throughout the Sierra foothill belt that can be made to serve hundreds of acres if development is undertaken. California is far behind some of the other western states in building storage works for impounding irrigation waters.[5]

[4] For full data on water supply see U. S. Geol. Survey Water Supply Papers Nos. 295, 296, 298, and 299; U. S. Dept. Agr., Office Expt. Sta. Bulls. 207, 237, 239, and 254.

[5] See U. S. Dept. Agr., Office of Expt. Sta. Bulls. 134 and 179. For additional data on the construction of dams see U. S. Dept. Agr., Office Expt. Sta. Bull. 249.

Colorado has added thousands of dollars to its wealth through the co-operation of farmers in constructing small reservoirs. Opportunities for such development are equally favorable in many parts of the Sierra foothills. The use of small reservoirs in connection with pumping plants is recommended, particularly in portions of the Tulare-Fresno citrus belt, where water is lifted about 150 feet and where the stream produced is too small for an economical irrigating head.

TULARE AND FRESNO COUNTIES CITRUS BELT

The chief citrus producing district north of the Tehachapi Mountains is found in the foothill area of Tulare County, of which Porterville, Lindsay, and Exeter are the principal towns. Other settlements are Ducor, Terra Bella, Strathmore, Lemoncove, Globe, Naranjo, and Woodlake. There are now about 40,000 acres of citrus trees under cultivation in this section, about one-quarter of which are in bearing. The shipments of oranges and lemons from this section are rapidly increasing and now amount to about 6000 cars annually.

Fig. 1.—Irrigated lands near Lemoncove, Tulare County

The Tulare and Fresno counties citrus belt extends northward through Fresno County, the principal orange development in this county being around Mount Campbell and Clarks Valley, and includes plantings north and east of Sanger. The area devoted to citrus fruits in Fresno County is about 2000 acres.

The hills bordering this part of the San Joaquin Valley rise rather abruptly and culminate in the Sierra Nevada. The citrus development occurs principally along the lower slopes and in several small valleys and coves back of the first range of hills; it is also rapidly spreading westward over the plains.

The climate of this section is arid and subtropical. The summers are hot and dry but the nights are usually comfortable. The mean monthly temperature and precipitation at Porterville is shown in figure 3. The average rainfall at Porterville for twenty-five years is 10.02 inches.

Fig. 2.—Irrigated citrus orchard on steep hillsides near Exeter, Tulare County

SOILS

The soils of this belt consist of material derived from the weathering of a wide range of rocks. Those on the steeper hills and slopes are mainly residual from underlying metamorphic and granitic rocks and contain some material from colluvial sources. They range in texture from loams to clay loam adobes and are brown to chocolate brown or nearly black in color.

The residual loams are usually brown and vary in depth from 1 to 6 or more feet. The soils are friable throughout the entire depth and are easily tilled. Humus and lime are present in moderate quantities and the surface is smooth and easily prepared for irrigation.

The clay loam is somewhat darker in color than the loam, but resembles it in other features except tillage. It is moderately well-supplied with humus and lime, is retentive of moisture, but is difficult to till on account of its heavy texture.

The residual clay loam adobe is chocolate brown to black and ranges in depth from 6 inches to 6 or more feet. The average depth is about 2 to 3½ feet. It has a granular structure when dry but is heavy and waxy when wet. The humus content is relatively high. In places the parent rock disintegrates into a white mass which has

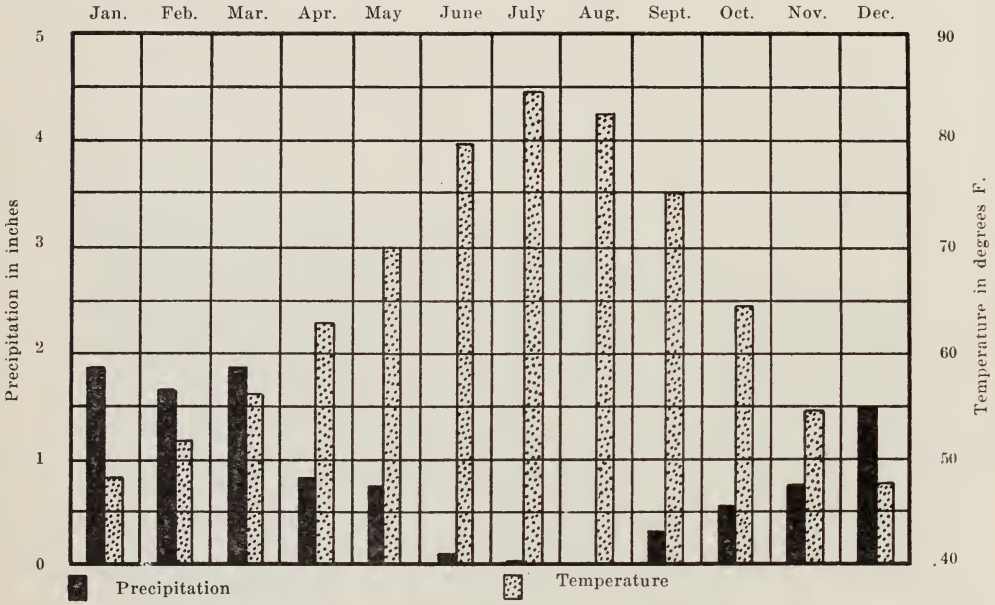

Fig. 3.—Mean monthly temperature and precipitation at Porterville, 1889–1913

been found to be prejudicial to the health of the trees. When well cultivated the type is retentive of moisture and appears to break down into a marly heap when exposed to oxidation. This type occupies a position above the alluvial adobes and is much more expensive to irrigate on account of its elevation. It occupies the steeper residual slopes and ridges in many of the coves and along many of the small foothill valleys. The residual soils are all well-drained and free from alkali except in a few local areas in small coves and valleys where intercepted drainage has caused alkali to accumulate.

Erosive agencies and moving water acting upon the rocks in the foothills have given rise to an irregular belt of adobe soils which follow

along the lower foothills from the region east of Delano northward to the head of Clarks Valley, a distance of about 75 miles. A narrow border of this material also occurs on the lower slopes of Mount Campbell and other ridges and hills to the north. These adobe soils generally occupy slopes varying considerably in steepness and are well-drained and free from alkali, except in local depressions and small valleys. They are high in humus and lime and rank among the most fertile soils in this region. They are mainly alluvial in character, are usually free from hardpan, and their naturally smooth surface requires very little leveling for citrus culture and irrigation. They are dark brown to nearly black in color and were recognized as belonging to the Porterville series of soils as mapped in that area by the Bureau of Soils.[6]

South of Porterville and east of Strathmore, adobe soils project into the valley as a series of ridges and slopes, somewhat higher than the surrounding country. The lower slopes are less steep as they approach the valley soils. Small quantities of sub-angular rock fragments and gravel are present locally, but they seldom interfere seriously with tillage and cultivation. The subsoil is usually a compact heavy clay, somewhat lighter in color than the surface and in places is very high in lime, making it almost white. This marly stratum is somtimes semi-cemented and resembles a hardpan, but generally the subsoil is free from unfavorable obstructions to root development. When dry the soil cracks badly and in places of unusually high lime content puffs or heaves when drying, forming a soft mealy area locally known as "dry bog." Whenever these soils have a gray limy subsoil layer at less than 5 feet they are considered of little value for citriculture on account of chlorosis. Tillage is usually a difficult operation on these soils, but when large amounts of organic matter are turned under and plowing is done at the proper time, the soil works into a well-granulated mealy condition.

The adobe soils were the first selected for citriculture because of their favorable location for frost protection, and are now the most highly developed in this belt. The higher and best protected slopes are used very successfully for lemon and pomelo growing.

Joining the adobe soils on their lower margin, and extending far out into the valley, is an extensive body of red to reddish brown loam and sandy loam. This belt of soils is underlain by a red indurated hardpan at depths of 6 inches to 4 feet and has a hog-wallow surface. The hardpan ranges from a few inches to 2 feet through. Beneath the hardpan the soil resembles the surface material and is well suited to root development. Where the hardpan is less than 4 feet beneath

[6] U. S. Dept. Agr., Bureau of Soils, Soil Survey of Portersville Area, California.

the surface, blasting is advisable for the best success with tree fruits.

The general surface of this body of soil is a gently-sloping plain, but is somewhat dissected at intervals by small stream valleys giving it an uneven ridgy appearance in such places. It is usually well-drained, but in small level or slightly depressed areas numerous bare spots indicate the presence of alkali. Elsewhere no alkali is found. This group of soils is fertile and responds with heavy yields where well handled. It is not quite so well protected from freezes as the higher lying adobe, but injury from this source seldom occurs and excellent success is being obtained with citrus fruits on it some distance west of the Southern Pacific Railroad. These soils are easily tilled and water for irrigation is obtained at shallower depths than on the soils nearer the foothills. The humus and lime content are much lower than in the adobe soils, but the lighter texture of this soil causes it to warm sooner in spring and gives it a wide range of beneficial cover crops. The acreage of this group of soils is perhaps two or more times greater than that covered by the adobe types.

Small alluvial valleys occur along Tule, Kaweah, and Kings rivers and along the larger creeks. These valleys are quite narrow where the streams emerge from the mountains but soon widen out into broad alluvial fans on entering the San Joaquin Valley. The soils in these stream bottoms are brown to grayish brown micaceous fine sandy loams and silt loams for 6 or more feet in depth. They are subject to overflow in places, but this can be avoided by levees. They are easily tilled and highly productive. Water is available at 15 to 35 feet below the surface and in a few low areas of restricted drainage the ground water is so near the surface that alkali has accumulated in injurious quantities. Small, highly-successful plantings of oranges are found on the Kings River bottoms about 10 to 12 miles northeast of Centerville, where the gradient of the river bed is sufficiently great to prevent damage from frost. Elsewhere these soils are too low for citrus culture but respond with high yields of peaches, plums, pears, figs, bush and vine fruits, truck, grain, and alfalfa. Before tillage these soils usually support a moderate growth of cottonwood, willows, and vines. The soils are retentive of moisture and contain no obstructions to deep root development.

On all soils of this belt care is exercised to avoid alkali-affected areas and low places where drainage is not good for fruit culture. Besides being more subject to freezes, the soils in such places are saturated with water for one or more months of the year during rainy periods, and such a condition is not conducive to the best welfare of the more sensitive citrus and deciduous fruits. The groves are generally

plowed once each year to turn under manure or cover crops and to aerate the soil. This plowing is followed by cultivation at frequent intervals through the spring, summer, and fall months to conserve moisture and check weed growth. On the heaviest phases of the adobe soils plowing is sometimes not practiced and the soil is kept stirred by discs and spring-tooth harrows. Where this practice is followed, one good man and four mules can handle about 80 acres except for the help of an additional outfit for about one month or six weeks during summer. Clean culture is the rule during summer, and cover crops, such as vetch, oats, rye, barley, and field peas, are extensively planted in the fall to supply the much needed organic matter. Considerable commercial fertilizer high in nitrogen and phosphoric acid is used, the amount generally increasing with the age and bearing of the trees. Navels are the principle oranges grown, but at present considerable areas are being set out to Valencias.

While the Tulare-Fresno Counties foothill belt is principally devoted to the growing of citrus fruits, the soil and climatic conditions are, as already indicated, favorable for the growing of a wide range of crops. Olives and figs are often planted to form borders or windbreaks for citrus orchards. Alfalfa is extensively grown at the foot of the slopes. The Southern Pacific Railroad parallels this belt from north to south and several small branch lines, besides an electric road, serve as outlets for small valleys located farther back in the foothills. These, with additional branch lines now under construction, place nearly all points in this belt, capable of development, within reasonable distance of a shipping point.

IRRIGATION

Water for irrigation is obtained both from gravity canals and by pumping from wells. Tule and Kaweah Rivers are the principal sources of gravity supply. The average monthly flow of Tule River at Porterville is 246 cubic feet per second, the greatest flow occurring from March to June, inclusive. There are 86 ditches and canals diverting water from Tule River, most of which irrigate valley lands below Porterville. The principal diversions from this river irrigating citrus lands are Pioneer Canal, South Tule Independent Ditch, Pleasant Valley Ditch, Mount Whitney Ditch, and Campbell and Moreland Ditch. The cost of water from these ditches varies from $2.50 to $8 per acre per season. Bonnie Brae and Lemoncove Ditches are the only ditches of importance irrigating citrus lands from the Kaweah River.

Utilization of underground waters for irrigation is important in this section. The average lift varies from 80 to 200 feet and in some cases water is raised more than 400 feet. These high lifts are not due to the depth of water below the land surface, but to raising the water to elevations on the hillsides. Most of the wells now drilled around Porterville are 12 inches in diameter and vary in depth from 80 to 350 feet. The cost of boring is $1.50 per foot for the first 100 feet in depth, and 50 cents per foot extra for each additional foot. The cost of casing is about $1.17 per foot.

Centrifugal pumps are used in this section for heads up to 80 to 100 feet. Where the lift exceeds this and wells do not produce over

Fig. 4.—Typical irrigation pumping plant near Lindsay, Tulare County

30 or 40 miner's inches of water, deep-well pumps are used. Electric motors are more generally employed than gas-engines, the power generally costing $50 per horsepower per annum. Various forms of contracts are made by the power companies according to the size of the plant and conditions involved.

The pumping installations about Porterville, Lindsay, and Exeter are similar to those in southern California, descriptions of which are given in a bulletin of the Office of the Experiment Stations.[7] A typical plant in the Plano district near Porterville, where the lift is 150 feet, consists of a 20-horsepower motor and a double-acting plunger pump

[7] U. S. Dept. Agr., Office Expt. Sta. Bull. 236.

having an 8-inch cylinder and discharging 270 gallons per minute. The well is 12 inches in diameter and 300 feet deep. This plant cost $2400 and it serves 40 acres of oranges.

The cost of preparing land for irrigation ranges from $10 to $40 per acre. The higher cost is for the uneven rolling land, locally called "hog-wallow," found at the foot of the slopes. The land is plowed as

Fig. 5.—Delivery of water from concrete standpipes

Fig. 6.—Concrete head-flume in hillside orchard near Porterville, Tulare County

deeply as possible with a heavy breaking plow and then levelled with a Fresno scraper and wooden drag or leveler. Where hardpan occurs holes are usually blasted before trees are planted.

The methods of applying water and the appliances for controlling water are similar to those in vogue in southern California. Concrete pipe is extensively used for ordinary slopes, but where water is carried over hills and subjected to pressure iron pipe is substituted. Concrete flumes following the contours of the hillsides are generally used in carrying the main supply. The cost, laid, of concrete pipe at Porterville is given as follows:

Diameter, inches	Cost per foot, cents
6	21
8	23
10	27
12	33
14	40

The cost of valves placed in head stands at the head of each row of trees is $2 each.

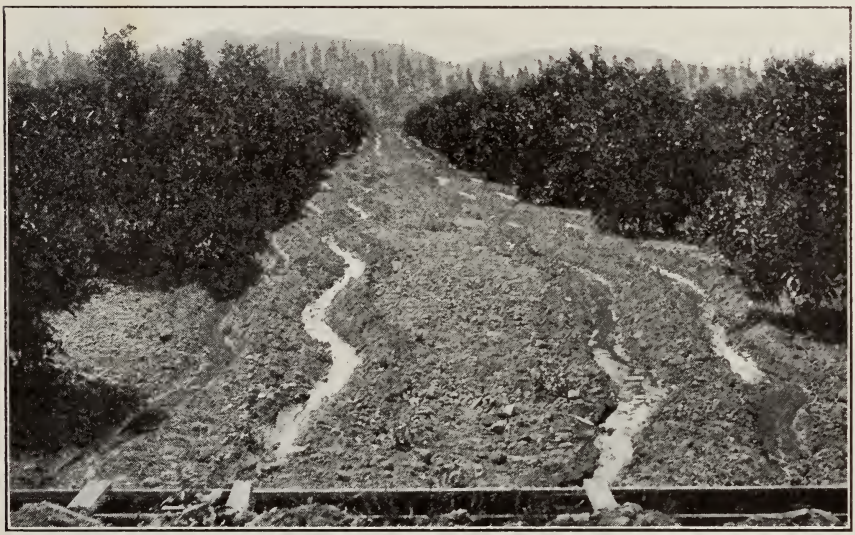

Fig. 7.—Curved furrows in Tulare County citrus orchard

The furrow method is used exclusively in the irrigation of orchards. In young orchards from 2 to 4 furrows 3 to 4 inches deep are run between the rows of trees. In bearing groves the furrows are made 10 to 12 inches deep, thus enabling the moisture to penetrate more deeply into the soil and insuring a deeper root system for the trees. To reduce the grade and lessen the washing of the soil, various schemes of furrow-

ing are employed. A common method is to curve the furrows, thus checking the flow of water, as shown in figure 7. On the Merryman ranch, at Exeter, a steep hillside is irrigated by means of 4 furrows between the rows of trees run down the face of the slope. The furrows next to the rows of trees are curved or zigzagged as shown in figure 8. The slope is so steep that only a stream the size of a lead pencil can be safely turned into each furrow. Around Lindsay, cross furrows are much used to give a more equal distribution of water over the surface than is possible with straight furrows, as is illustrated in figure 9. Furrows are made parallel to the head line and then crossed at right angles by furrows running down the steepest slope. The work of making the necessary cuts and fills is done by hand or with a jump scraper.

The streams of water or heads used in irrigating orchards are from 20 to 60 miner's inches in size. The size of the stream allowed to run in each furrow and the length of the furrow vary with the slope and character of the soil. On steep land, one miner's inch is divided into 4 or 5 parts which are allowed to trickle down the slope. On moderate

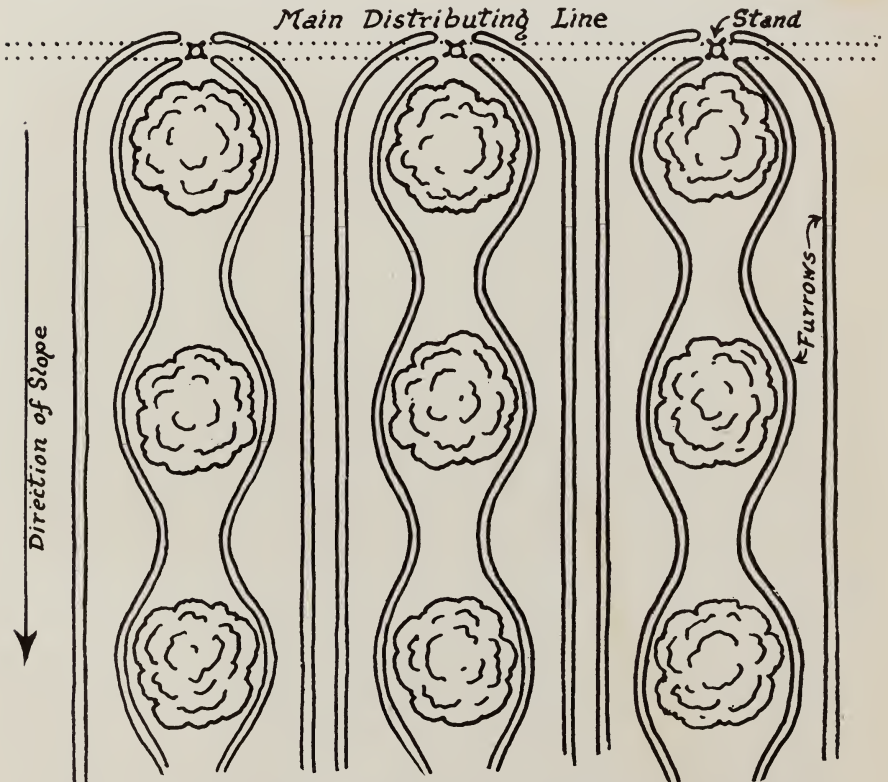

Fig. 8.—Diagram showing combination of straight and curved furrows near Exeter, Tulare County

slopes the furrows are made 400 to 600 feet long and the head increased to one-half miner's inch for each furrow. The irrigation season extends from April to November. Water is applied every 4 to 6 weeks, depending upon the season. After each irrigation the orchards are thoroughly cultivated to retain the moisture. The cost of irrigating citrus fruits by pumping is higher than from gravity ditches. Where water is raised 150 feet, the cost of pumping will be in the neighborhood of $15 per acre per season.

Studies of the duty of water in the Tule River Basin were made in 1901 and reported in Office of Experiment Stations Bulletin No. 119.[8] The averages of a large number of measurements show that the depth of irrigation for citrus trees varied from 1 to 2 feet. A depth of 1.5 feet for full bearing trees on adobe or loam soil seems a sufficient allowance where the rainfall is 10 inches, although the best amount to apply of course varies with different orchards. It is the opinion of successful growers in this belt that less water is required to irrigate the adobe slopes than the more level red hog-wallow valley soils.

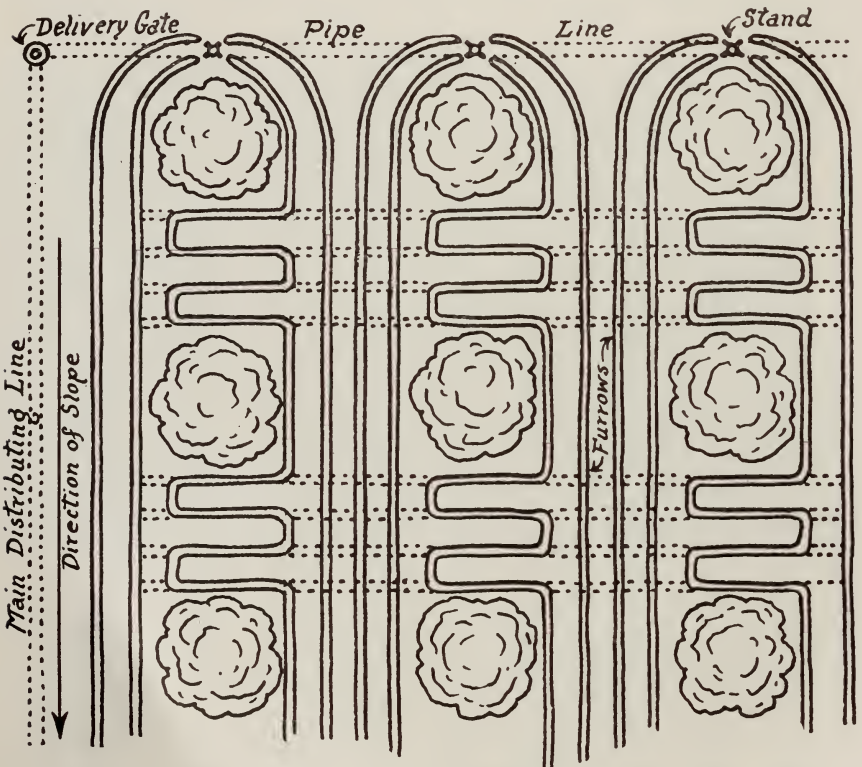

Fig. 9.—Diagram of zigzag furrows in a Lindsay (Tulare County) orange orchard

[8] U. S. Dept. Agr., Office Expt. Sta. Bull. 119, pp. 159–189.

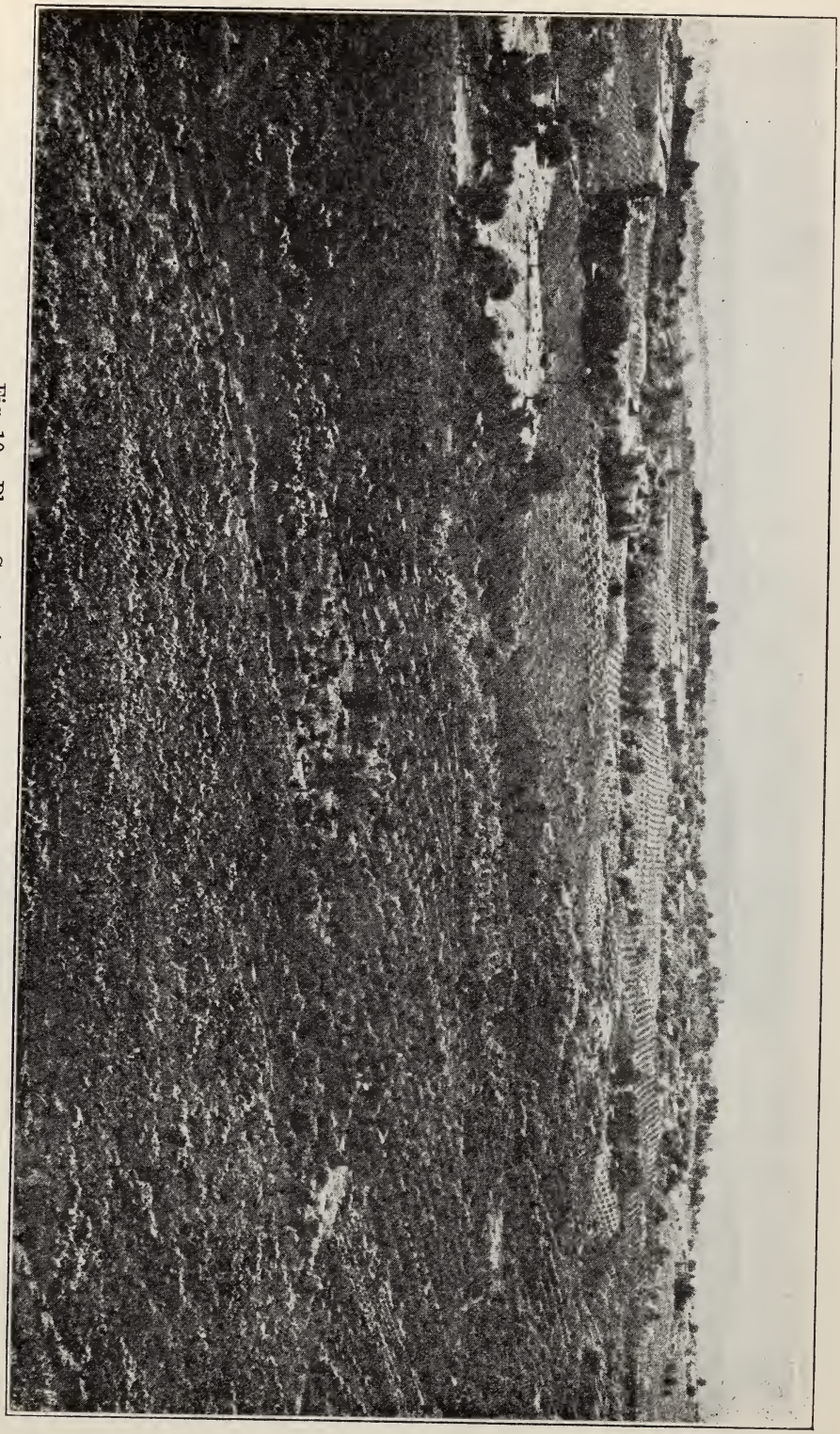

Fig. 10.—Placer County irrigated foothill orchard near Penryn

PLACER COUNTY DECIDUOUS FRUIT BELT

Placer County is nearly in a line west of the State of Delaware. It extends from the Nevada line southwestward well out into the Sacramento Valley and has a topography varying from level plains 40 feet above sea-level to very rugged, broken, and dissected rocky areas from Colfax eastward. Its extreme elevation is about 7000 feet. The main development in the foothill section of the county is around Auburn, Newcastle, Penryn, Loomis, and Rocklin. The area is utilized principally for the growing of deciduous fruits, and it ships to outside markets about one-quarter to one-third of the total output of fresh fruit of the state. Peaches, plums, and grapes are the main fruits grown, with moderate plantings of pears, figs, olives, apricots, cherries, and persimmons.

Fig. 11.—Lower Sierra foothill orchard near Loomis, Placer County

The wide variations in topography, climate, and soils of this belt have an important bearing upon the kinds of fruit best suited to the region. Auburn, with an elevation of 1360 feet, marks the upper boundary of orange culture and the lower limit of commercial apple growing. Deciduous fruits, except pears and apples, decrease in commercial importance east of Colfax, which has an elevation of about 2400 feet. From this point up to about 3000 feet apples and Bartlett pears reach a high state of perfection.

Like other sections of the foothills this district has but two seasons, the rainy and the dry. The average rainfall during the months of June,

July, August, and September amounts to only one inch. The moisture absorbed by the soil from the rainfall is sufficient to start an active growth, but irrigation is usually necesssary for the maturing of the fruit crop. The mean monthly rainfall at Auburn is shown in figure 12, which illustrates the dry season from May to October, when irrigation is practiced. The average yearly rainfall is 35.13 inches.

SOILS

The soils around Rocklin, Loomis, Penryn, and Newcastle are light, reddish sandy loams and loams derived principally from underlying granodiorite, and influenced in local places by andesitic tuff, which imparts a high iron content and a redder color to them.

The sandy loam here ranges in depth from 1 foot to 6 or more feet. It is usually of uniform texture to the underlying bedrock, which is

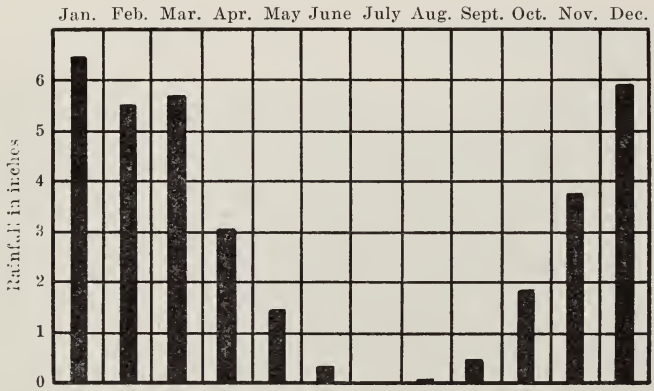

Fig. 12.—Mean monthly rainfall at Auburn, 1872–1913

often partially weathered many feet deep. A tendency exists in this type for the finer soil particles to filter downward causing a layer of red sandy clay from 6 inches to 1 or more feet thick to form at 1 foot to 4 feet below the surface. This layer is beneficial in checking the downward movement of water, which is usually excessive in this soil. The type occupies a rounded, hilly topography, with moderate to gentle slopes favorable for irrigation. The type is low in humus, but responds quickly to organic matter and good care.

The loams here are light grayish-brown to gray in color and range from one foot to 6 or more feet deep. They are easily tilled and need organic matter for the best returns. These soils usually occupy a lower position than the sandy loams and are more gently-rolling. Much of

the material consists of fine particles washed from the higher-lying sandy loams. They retain moisture somewhat better than the lighter types.

The soils above described are easily tilled and the rolling topography gives them good drainage. The excessive use of irrigation water, however, has frequently caused a water-logged condition in the bottoms of the small valleys which in time may develop alkali unless preventive measures are adopted. Rock outcrop is not uncommon but the soil is generally of sufficient depth for successful fruit culture. The soils are not quite so enduring as those around Auburn but they warm up more quickly and mature fruit from 1 to 2 weeks earlier than in the latter section.

Fig. 13.—Irrigated orchard near Rocklin, Placer County

manure. Some cover crops are grown. The prevailing practice is against summer cultivation, and some successful growers hold strongly to the opinion that clean cultivation is injurious. For 15 years one large grower has practiced biennial cultivation, plowing only one-half of his orchard each year while burr clover and other native plants and

Little cultivation is done in the orchards during the summer months and the weeds and grass which spring up are plowed under for green weeds are allowed to grow and seed undisturbed for a full year, both mature growth of later spring and summer and the green growth of the following winter being turned under in March and April. Growers generally justify the practice of no summer cultivation on the grounds that the frequent irrigations—these are given every 10 days or 2

weeks from May to September—make moisture conservation by cultivation unnecessary, that the weed growth increases moisture absorbtion and decreases soil erosion from the winter rains, that winter growing of manuring crops to take the place of the summer growth of native grasses has not yet been found feasible, and that the expense of frequent summer cultivations and the constant re-making of the irrigation furrows would not be justified even if desirable. In the lower sections of the belt, as about Penryn and Loomis, vetches have been more successfully grown in winter than about Auburn and Newcastle and, as a consequence, summer cultivation is more general.

The soils around Auburn consist mainly of deep red loams and clay loams, derived principally from amphibolite. They are known

Fig. 14.—Slate soil near Auburn, Placer County, showing depth and character

to be highly productive and very enduring. What is lost in earliness on these soils is made up by increased yields. The rocks giving rise to these soils occupy a nearly vertical position and their manner of disintegration gives rise to a series of ridges and hills, while the granodiorite weathers into a more subdued topography and gives rise to an extensive series of more gently sloping rounded hills. The same methods of farm management are followed on these soils as prevail in the Newcastle-Penryn belt.

The loams about Auburn average about 3 to 3½ feet deep but frequently extend to depths below 6 feet. They are red in color, friable, are relatively low in humus, and are easily tilled. The topography is favorable for fruit growing and few rock outcrops occur except in

places too steep for agriculture. The soils are relatively high in iron and retain moisture well. Peaches, pears, grapes, figs, olives, cherries, and plums are the leading fruits.

The clay loam about Auburn is uniform in texture from 2 to 6 or more feet deep and is of a deep red color. It is a durable soil but is somewhat difficult to till on account of its heavy texture. It is well-granulated, however, and retains moisture well. The soil rests on bedrock and occupies a topography similar to the loam. The clay loam is well adapted to a wide range of fruits, chief among which from Auburn eastward are apples and pears.

Fig. 15.—Typical rolling foothills near Colfax, Placer County

The loams and clay loams around Newcastle are well-drained and free from alkali. Surface features are favorable for fruit culture and irrigation without leveling, but the clearing of brush from virgin land is necessary in most places before crops can be grown. Some gravel is present locally but does not seriously interfere with tillage.

Beginning about 4 miles northeast of Auburn, the soils suitable for fruit growing narrow down to a belt ½ mile to 2 miles wide, paralleling the railway to Colfax. Outside of this narrow strip the region is rough and suited only to grazing, mining and lumber production. The soils are reddish loams and clay loams from 1 foot to 6 feet deep and are derived mainly from slates and diabase. They are highly productive soils and yield pears and apples of excellent quality. Plums,

peaches, and other deciduous fruits are also grown successfully, but the increased elevation makes them later in maturing. The granitic rocks in most cases underlying the greater part of this region have partially or fully disintegrated to considerable depth and the jointed and seamed structure of the upturned rocks permits of a ready downward movement of excess water. Where the soil covering is not thick, blasting is frequently done after which the blast hole is filled with surface soil and the trees planted. There is ample opportunity for surface waters to drain away from the basins formed, and excellent results are obtained from this practice.

Fig. 16.—Irrigated orchard near Auburn, Placer County

IRRIGATION

The Placer County fruit district receives water from ditches owned by the Pacific Gas and Electric Company, which obtains its water supply from Yuba and Bear rivers. The present system represents largely a consolidation of old mining ditches which have been reconstructed and are now utilized for power and irrigation; a large part of the water, however, is still being used for mining operations in Nevada County. The company utilizes 20 lakes and reservoirs and has recently enlarged its supply by the construction of a concrete dam at Lake Spaulding. When the system is completed the water will be used six times in power development in addition to being used to irrigate a considerable area of foothill orchards. An important feature of the development work being undertaken by the Pacific Gas and Electric Company is the enlargement of Bear River Canal which supplies water

for irrigation purposes. This canal diverts water from Bear River near Colfax, from whence it is carried to lakes Theodore and Arthur and there distributed in various ditches. At present something over 15,000 acres are irrigated, but the enlargement of Bear River Canal together with the increased storage at Lake Spaulding, will make possible the irrigation of an additional 20,000 acres of land, more or less. The original Bear River Canal was constructed in 1851 by hand labor and delivered water to Auburn and vicinity for mining purposes.

The Boardman Canal is one of the main branches supplying the divide between Bear River and North Fork of American River. It

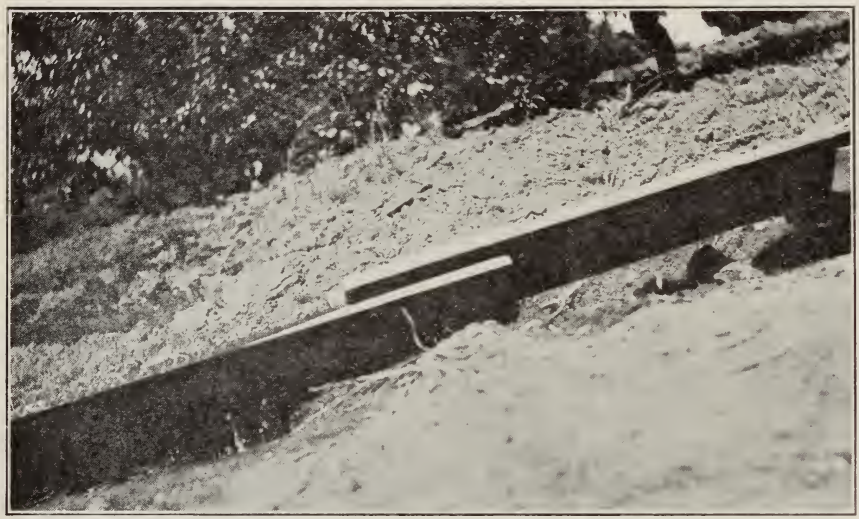

Fig. 17.—"V" flume used for conveying water down steep slopes, Placer Co.

closely parallels the Southern Pacific Railroad and extends to Rocklin, a distance from the point of beginning of 77.3 miles. Gold Hill Canal is another part of the general system, this canal has a separate diversion from Bear River about 12 miles downstream from the head of Bear River Canal. The entire distributing system embraces about 265 miles of canals, pipe lines and flumes.

The delivery of water on this system is different from that on any other in the State. This is due mainly to the hilly character of the land irrigated and to the peculiar methods of irrigation used. The use of large heads of water is impracticable and it is the custom to deliver to consumers a small but continuous stream. Under present practice 1 inch of water usually serves from 5 to 8 acres, this amount being shifted from one part of the orchard to the other as occasion requires. The irrigation season extends from May 1 to October 1. Water is sold

at the rate of $45 per miner's inch for the season. The records of the company show that the use of water on the system as a whole is 1 miner's inch to 5 acres, which makes the average cost of water to irrigators $9 per acre per season. Many of the best orchardists, however, use about 1 miner's inch to 7 acres. The company delivers water to anyone making application and the purchase of a water right is not required. The use of 1 miner's inch on 7 acres would cover the land to a depth of about 1 foot for the irrigation season exclusive of rainfall. In Pomona Valley, southern California, where water is pumped at great cost, 1 miner's inch serves to irrigate 8 acres of citrus fruits and

Fig. 18.—Single irrigation furrow and clean cultivation near Penryn, Placer Co.

the total depth applied, including rainfall, is about 3 feet, or about 1 foot less than at Auburn. At Riverside, where canal water is used, the depth of irrigation is from 2 to 2¼ feet and the average rainfall brings the total up to about 3¼ feet.

Water is measured to consumers through miner's inch boxes. The miner's inch as used in this section is the quantity of water that will pass through an orifice 1 inch square under a head of 6 inches above the center of the orifice. It is equal to 11¼ gallons per minute or 1/40 of 1 cubic foot per second. A wooden tube or box is placed in the side of the ditch bank or levee so that the center of the opening is 6 inches below the water line of the ditch. No provision is made for fluctuation or change of head in the main supply. This system of distribution requires careful maintenance and regulation of flow into the ditches. The company has made actual volumetric measurements of

the water delivered to each irrigator and has established bench marks whereby the discharge of a box can be ascertained at any time.

The furrow method is universally adopted in orchard irrigation. The steep hillsides are planted to orchards and various ingenious methods are used to surmount the difficulties of irrigation and the liability of eroding the soil by running water. A common method consists of running one furrow down the steepest slope for each row of trees and making a semicircle around each tree, as shown in figure 19. The semicircle reduces the grade of the furrows and consequently the velocity of the water, thus preventing erosion. If the land slopes in two directions, the water is carried around the tree on the uphill side at a distance calculated to serve the greatest number of roots. The slope of the land is supposed by the growers to be sufficient to carry the water to the roots on the lower side of the tree. Instead of a semicircle, a pocket or small hole is often made above each tree and is kept full of water. This serves to replenish the furrow and to hold the water until it can sink into the soil. Occasionally furrows are run on a contour or water grade as shown in figure 21. The principal objection to this method is that in case the flow in any furrow is obstructed or a break occurs, the water flows down the slope to the next furrow below, and so on, which in turn overflows, often causing much damage by washing. Gophers and ground squirrels cause many breaks in ditches and furrows, and in case of the furrows these are most apt to cause trouble where the contour method is used. Iron pipe varying from 1 to 4 inches in diameter is used to convey water across depressions and to tops of hills.

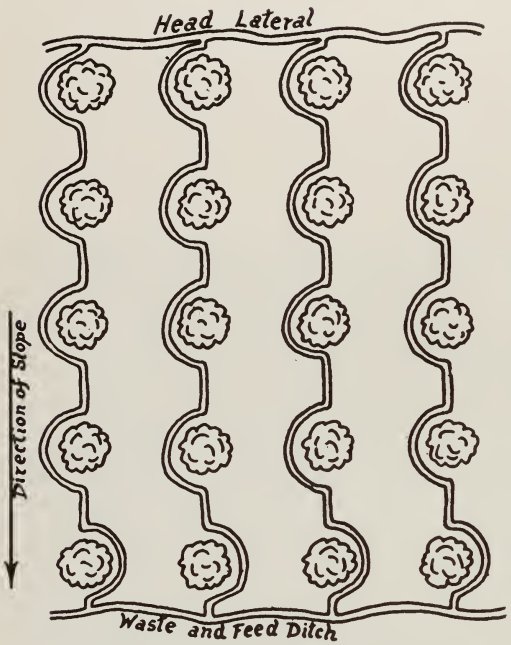

Fig. 19.—Diagram showing semi-circle irrigation furrows around trees, Placer County.

The amount of water allowed to run in each furrow depends upon the slope of the land. In some cases, 3 or 4 gallons a minute is sufficient to reach the end of the row and not cause washing of the soil. The

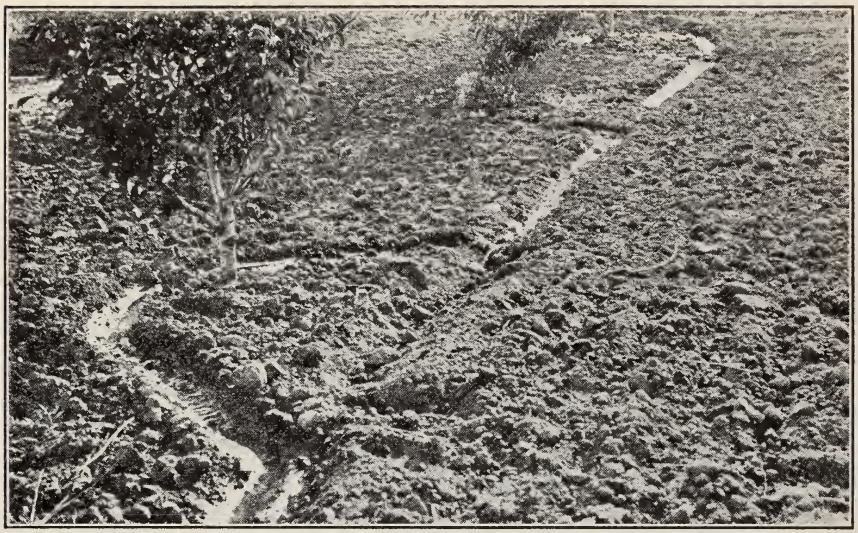

Fig. 20.—Photograph showing semi-circle irrigation furrows around trees, Placer County

length of the furrow varies with the grade and size of the orchard. Ordinarily furrows are made about 600 feet long. The time and length of irrigation vary with the maturing of the crop. Generally water is applied about every two weeks and allowed to run in the furrow from 24 to 48 hours. It is then changed to other parts of the orchard until the whole is covered. During the time the fruit is sizing or swelling, irrigations are more frequent.

Observations made in some of the orchards indicate that most of the water applied finds its way below the great mass of roots to bedrock, whence it must be raised by capillarity, if it is to be of any service to the trees. That much water is lost as underground flow along the inclined bedrock surface is evidenced by the seepage at the line of

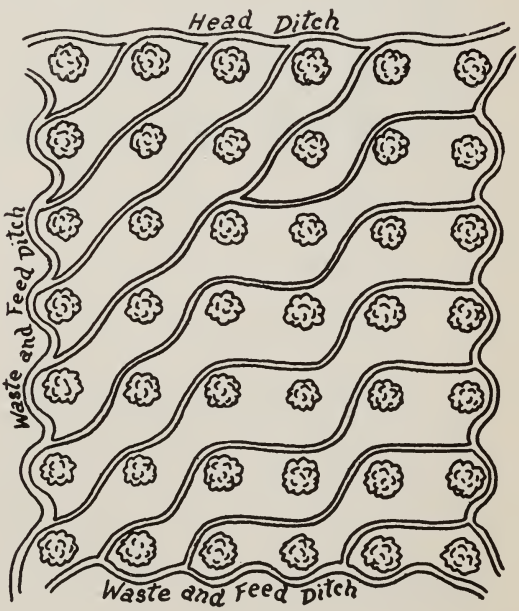

Fig. 21.—Diagram of typical furrow and ditch arrangement, Placer County orchard

bedrock in excavations and by the fact that many orchards on the lower levels require little irrigation. If this loss could be obviated without decreasing the efficiency of the irrigation and without excessively increasing the cost, the duty of water could be increased.

BUTTE COUNTY FOOTHILL AREAS

Irrigation development in the Butte County foothills centers mostly around Oroville in Thermalito and Palermo colonies and near the towns of Wyandotte and Bangor. Other development is found at Paradise and Cohasset.

OROVILLE SECTION

Oroville is located on the eastern edge of the Sacramento Valley on Feather River. Undulating hills rise gently to the east, followed by a series of ranges gradually increasing in height until the crest of the Sierra Nevada is reached. The mountains in this part of the range are not so lofty as in other parts of the State. They are heavily covered with timber and the lower foothills support a coarse growth of chaparral, scrub oak, and "digger" pine. The country around Oroville is adapted to nearly all kinds of fruit, but olives and oranges are the principal fruits now being planted.

The climate at Oroville and vicinity is typical of Sacramento Valley. The summers are hot and dry with cool nights in the higher altitudes. The winters are mild and equable. The mean monthly temperature and precipitation at Oroville for seasons 1885 to 1913, inclusive, are shown in figure 22. The mean annual rainfall is 28.40 inches.

Soils

The soils in the Oroville region covered by this report including the Thermalito and Palmero colonies consist of alluvial and sedimentary deposits of great age. They are gravelly loams, sandy loams, loams, and clay loams of red to reddish-brown color.

The gravelly loams range in depth from 2 to 4 feet and rest upon a hardpan which varies in thickness from 6 inches to 2 feet and is underlain by beds of gravel. The soil is usually low in humus and responds readily to organic matter. The gravel present makes tillage

difficult. This type is well to excessively drained and has a sloping to slightly hilly topography.

The sandy loams consist of 2 to 6 feet of friable soil generally underlain by a dense hardpan. Beneath the hardpan the material is loose and friable in most places, but in other places gray cemented beds extend beneath the hardpan to depths of many feet. Blasting where the hardpan is shallow results in greatly increased yields, but where underlain by other cemented beds it forms a bowl which holds water thus creating an unsanitary condition for plant roots.

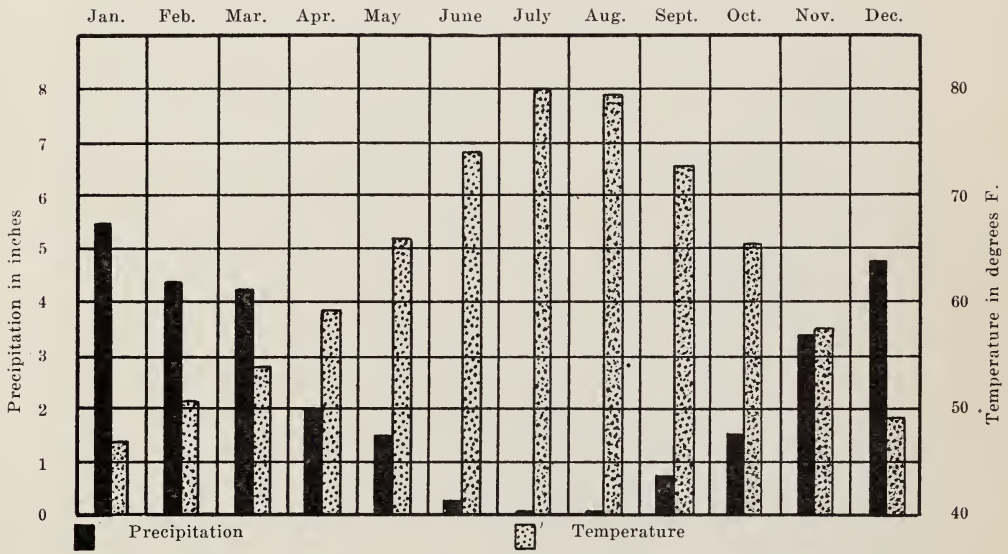

Fig. 22.—Mean monthly temperatures and precipitation at Oroville, 1885–1913

The loams and clay loams range in depth from 1 foot to 4 feet and are red to reddish-brown in color. They are more difficult to till than the lighter types but generally retain moisture longer when given good attention. They rest on hardpan at various depths and generally have a hummocky surface. The loams and clay loams generally occupy lower and more level areas than the lighter types. Organic matter greatly improves these soils.

Bodies occuring along stream courses are overflowed somewhat during periods of high water.

Considerable citrus plantings have been made on the higher and better protected slopes with good success. Experience has shown, however, that it is generally advisable to avoid valleys and level or

slightly depressed areas for such fruits on account of freezes and stagnated drainage through the winter months. The more level and gently sloping areas are very well adapted to the growing of olives, peaches, grapes, figs, other deciduous fruits, grain, and alfalfa.

Irrigation

Thermalito colony comprises about 1000 acres of oranges, olives, and figs, situated on the rolling plains across Feather River, north and west of Oroville. The subdivision of the land in this neighborhood was made about 1888 and during the next few years approximately 700 acres of trees were planted. Water is supplied by the Oro Water, Light and Power Company and development here has been possible only through irrigation. The Company diverts water from the west branch of Feather River, about 30 miles from Oroville, in what is known as the Miocene Ditch, which was originally built for mining purposes and is now used for both power and irrigation. Water is delivered through the colony in iron pipes, as the configuration of the country makes open ditches impracticable. Hydrants are installed at each point of delivery to regulate the flow of water to consumers. Water is sold to irrigators at a flat rate of $5 per acre per annum. This plan of selling water encourages wasteful practice, evidence of which is seen in the waterlogging of the lower levels, which now need artificial drainage. With an irrigation season of five months, and a continuous flow through the pipe lines of 8 cubic feet per second, sufficient water is carried to supply the land irrigated to a depth of 3 feet.

Palermo Colony lands are situated about 6 miles south of Oroville. The highest irrigated lands are about 600 feet above sea-level, but the greater part of the irrigated area lies below an elevation of 300 feet. Water is supplied by the Palermo Land and Water Company, a corporation that colonized the land in 1888. Water is diverted from South Fork of Feather River about 21 miles above Oroville.

The irrigated area in Palermo County comprises about 2000 acres of oranges, olives, and peaches, the greater part of the planted area consisting of bearing orchards. Water is sold to irrigators at the rate of 12½ cents per miner's inch for 24 hours. With an average of 5 irrigations during the season, the cost of water varies from $3 to $7 per acre.

Water is applied once every four weeks, and is allowed to run in the furrows from 24 to 48 hours. The furrows vary in length from

500 to 1000 feet. The head of water used in each furrow varies with the slope and character of the soil. Ordinarily, 1 miner's inch to each furrow will sufficiently reach all parts of the land. Generally 4 furrows are run between the trees. Some orchardists use fewer furrows during the early age of the tree to induce deep rooting. After each irrigation the land is cultivated from 2 to 4 times.

Measurements made in 1912 showed that the average duty of water for oranges was 1.27 acre-feet per acre, and for olives, 1.23 acre-feet per acre.[9]

WYANDOTTE-BANGOR SECTION

The soils around Wyandotte and Bangor, southeast of Oroville, are mainly residual from schists. Local areas of old stream and shore gravel occur in this belt, which add difficulty to tillage on account of the cobble and gravel present in the soil. The schists give rise to red clay loams and loams. These soils vary in depth from 2 to 6 or more feet and rest on upturned jointed rocks. The texture is uniform to the underlying rock. The loams usually occupy a somewhat higher elevation, are lighter in texture, more friable, and easily tilled. Small areas of gravel occur within the loams and clay loams but they offer no serious obstruction to agriculture.

South Feather Land and Water Company supplies water to the land around Wyandotte and Bangor and also to a few scattered tracts around Forbestown and Swedes Flat. The Company has succeeded to the rights and properties of the Forbestown Ditch Company. The water supply is taken from Lost Creek, Orlova Creek, and Pinkard Creek, tributaries of Feather River. The irrigated area comprises about 1200 acres of oranges, olives and deciduous fruits. The cost of water to irrigators is $36.50 per miner's inch per annum, which amounts to about $6 per acre. Ultimately irrigation by South Feather Land and Water Company is expected to approach 7000 acres of foothill land around Wyandotte and 2000 acres of foothill land around Bangor.

PARADISE RIDGE

Paradise Ridge lies about 15 miles east of Chico, between Butte Creek and West Branch of Feather River. There are about 12,000 acres of land available for agriculture in this belt, the mean elevation approximating 2000 feet. The region consists of long sloping ridges

[9] U. S. Dept. Agr., Office Expt. Sta. Bull. 254, pp. 53–55.

and narrow valleys and it is well protected from winds and freezes. The slope is south and southwest and the fall is ample for good drainage and freedom from alkali. The soil is a deep red fertile clay loam to loam and usually contains more humus than the plains soils below. It varies in depth from 1 foot to 10 feet, with an average usually sufficient for the best development of fruit trees. The soil and subsoil are quite similar in texture, but the color becomes lighter as the depth increases until the soil gradually merges into light brown or light yellowish-gray andesitic tuff, from which it is derived. The slope of the region gives it good drainage and no trouble from alkali is present. Considerable timber covers much of the undeveloped land and in many instances is sufficient to pay for the clearing. The soils are tilled with moderate ease and very little grading is necessary for irrigation.

The water supply comes mainly from Little Butte Creek through a small ditch owned by the Oro Water, Light and Power Company. The irrigated area comprises about 600 acres and an additional 100 acres is watered by the old Cherokee Mining Ditch. Irrigation extension on the Paradise Ridge depends upon an increased water supply. Most of the water is now used in the development of power, and storage will be necessary for future development. A large supply of irrigation water per acre is not needed, and it is estimated that 1 acre-foot per acre per annum delivered at the small holdings would suffice for most of the area.

COHASSET RIDGE

Cohasset Ridge begins about 12 miles northeast of Chico, and lies between Chico and Rock creeks. The ridge is about 14 miles long, and ranges in elevation from 1500 to 3500 feet. The topography consists of long ridges and small valleys of steeper grade than those in the Paradise Ridge section. Brush covers the lower part of the ridge, but is replaced by oak, cedar, and pine with increase in elevation.

The soils of Cohasset Ridge are somewhat similar to those of Paradise Ridge and are derived from andesitic tuff. No extensive plantings of fruit have yet been made, and that which is grown is matured without irrigation. The products of this region are hauled to market by wagon.

SHASTA AND TEHAMA COUNTIES

The foothills in Shasta and Tehama counties include an irregular, broken area east of Cow Creek and Sacramento River from Bella Vista southward to the Butte County line, a few miles southeast of Vina.

The tillable land in this belt in Shasta County, counting the small pockets along the creek bottoms and suitable slopes, ridges, and hills, amounts to about 24,000 acres. Nearly 10,000 acres of this is along North and South Cow, Oak Run, Upper Bear, and Clover creeks. That part in Tehama County covers about 46,000 acres and is confined to a narrow belt along the margin of Sacramento Valley as far north as Red Bluff.

The elevation of the Shasta and Tehama foothill lands ranges from about 400 to 2000 feet. The rainfall at the lower margin is about 20 to 26 inches yearly and increases with elevation. The soils suitable for agriculture occur as small alluvial deposits along streams, as residual material on the slopes and ridges, and as gravelly bench lands, jutting into the margin of the Sacramento Valley. The first named deposits range from fine sandy loams to heavy silt loams and they are in most cases uniform in texture to 6 feet deep. They are well drained and free from overflow except in local depressions and flat areas along stream channels. No alkali is present and the soils are tilled with ease. They are grayish-brown to reddish-brown in color, are retentive of moisture, and respond to organic matter. They are utilized for the growing of clover, timothy, grain, alfalfa, truck, and deciduous fruits. The tillable areas at high elevations consist of red loams and clay loams of uniform texture from 1 foot to 6 feet deep. No hardpan is present and the soils rest upon the parent rock. The clay loams usually occupy slightly lower elevations than the loams, but both are well drained and free from alkali. They contain a small to moderate amount of humus and the small amounts of gravel occasionally present offer little obstruction to tillage. The rough areas are timbered and are used for grazing.

Water is obtained from numerous small streams and creeks. The present irrigated area comprises about 10,000 acres. Filings have been made on nearly all of the streams for power purposes and numerous areas formerly irrigated have been purchased by power companies and the use of water changed from irrigation to power. Agricultural development will depend largely upon the attitude of the power interests and upon transportation.

YUBA COUNTY

The foothill section of Yuba County suitable for agriculture lies mainly between the 200-foot and 500-foot contours. It is a narrow belt about 5 or 6 miles wide, beginning a few miles east of Wheatland and following the lower extension of the Sierra Nevada to Honcut Creek, a distance of about 20 miles. The main development is in Browns Valley, about 13 miles northeast of Marysville.

Fig. 23.—Typical rolling foothills near Browns Valley, Yuba County

The surface features consist in a series of low rolling hills interspersed with small narrow valleys. A growth of brush and scrub oak constitutes the native vegetation. The rainfall is between 20 and 25 inches and is not sufficient to produce crops satisfactorily without irrigation.

The soils are red clay loams and loams, derived principally from diabase, schist, and andesitic tuff. They are fertile and usually of sufficient depth for successful fruit culture. They are more deficient in humus than soils at higher elevations. The clay loams average about 2 to 3 feet deep, are of uniform texture, and rest on upturned rocks at various depths below the surface. The loams are similar to the clay loams in depth, but are lighter in texture. Both types are relatively low in humus, well drained, and free from alkali. They are too shallow for fruit culture in many places, being underlain by

thick, gray, cemented beds near the surface. Elsewhere a layer of hardpan is present. Some clearing is necessary before planting to fruits.

Browns Valley Irrigation District was organized in 1888 under the Wright Irrigation District Act, and comprises about 44,500 acres. This district has labored under the difficulties and discouragements which have attended similar attempts to form irrigation districts. Construction of the canal system was commenced in 1889 and was completed in 1893 at a cost of about $175,000. Water is diverted from North Fork of Yuba River above its junction with Middle Yuba. The main ditch is 48 miles long and water is distributed throughout the district by 5 principal branches; 10,500 acres of the district are above the ditches, and of the part below the ditch it is estimated that only 5000 to 8000 acres can be irrigated. About 1750 acres were irrigated in 1913.

In 1896 Browns Valley Irrigation District granted a fifty-year franchise to the Pacific Gas and Electric Company for the use of its entire appropriation of 10,000 miner's inches for the development of power, in return keeping the ditches in repair for the District. Water is distributed by employees of the District and to meet this expense a charge of $3 per inch per season is made. The duty for alfalfa is considered about 1 inch per acre, thus making the cost about $3 per acre per annum. For orchards about 1 inch to 3 or 4 acres is considered necessary. The principal irrigated crops are alfalfa and clover. All kinds of fruits can be successfully grown, but most of the orchards have been poorly kept and have a deserted appearance. Alfalfa is irrigated by flooding from field ditches and satisfactory yields are obtained.

SACRAMENTO COUNTY

A belt of low foothills about 6 miles wide follows along the east side of Sacramento County. It covers an area of about 150 square miles and varies in elevation from about 200 to 700 feet.

The topography of this foothill section varies from rounded hills to benches, slopes, ridges, and deep narrow winding valleys. The eastern half of this belt is underlain by alternating areas of diabase, slate, and schist, extending in a northwestern and southeastern direction. These rocks have disintegrated into red and yellow friable loams and clay loams. The soils from these rocks range in depth from 1 foot to 6 feet and in most places are sufficiently deep for fruit culture without blasting. Drainage is good to excessive. Varying amounts of brush

and stone are present in places, which require moving before crops can be planted. No alkali is present and no drainage from overflow occurs. With irrigation a wide range of profitable fruits is possible.

West of this belt the soils are derived from old shore and river gravels and from gray beds of clay, all of which usually contain a cemented layer at various depths below the surface. A number of intermittent streams occur in the belt which have carved out small, narrow valleys and deposited recent alluvium along their courses. The soils of the lower belt consist of red gravelly loams and gray to brown loams, and range in depth from 1 foot to 6 feet or more. In

Fig. 24.—Irrigating an orange orchard near Fairoaks, Sacramento County, with two furrows and with sacks in head-ditch to prevent washing

places a hardpan is present and blasting then becomes necessary for the best returns.

The main development in the Sacramento foothill belt is around Fairoaks, Orange Vale, and Folsom, about 15 miles northeast of Sacramento. Elsewhere the land is dry-farmed to grain or used as pasturage. More than 60,000 orange trees have been planted in the Fairoaks and Orange Vale colonies. Large plantings of olives, almonds, grapes, figs, peaches, some cherries, and apricots have also been made. There are many other favorable locations in this belt for the above mentioned crops as soon as irrigation is provided.

Most of the area, except around Michigan Bar, is moderately well supplied with transportation facilities and is well connected with Sacramento and other valley points.

The country in the vicinity of Fairoaks and Orange Vale is now supplied with water by the American Cañon Water Company, which purchased the rights and properties of the North Fork Ditch Company in 1908. For many years the ditches were used for mining purposes for which they were originally built. Water is diverted from North Fork of American River a few miles below Auburn by means of a masonry dam 310 feet long and 25 feet high. The main canal follows along the general line of American River for a distance of 25 miles to a subreservoir about 2 miles northeast of Folsom. The present irrigated area comprises about 4600 acres, mostly in orchards. The

Fig. 25.—Testing depth of percolation with 6-foot steel rod near Fairoaks, Sacramento County

irrigation season extends from about May 1 to October 1. Water is sold at a flat rate of $3 per acre per season.

EL DORADO COUNTY

El Dorado County, south of Placer County, extends from the foothills in the vicinity of Folsom easterly to Lake Tahoe and the Nevada state line. The American and Cosumnes rivers traverse the county and divide it into a series of irregular and undulating plateaus cut by steep ravines and gulches. The hills are generally covered with a coarse growth of underbrush, small oak, and a second growth of yellow pine. In the higher altitudes are valuable forests, which are included in El Dorado National Forest Reserve.

El Dorado County attained fame from being the first county in which gold was discovered in California. A few fruit trees planted by the early miners demonstrated the success of fruit growing and this promises to be an important industry. The annual shipments of fruits from Placerville now amount to about 250 carloads and the shipments will rapidly increase as young orchards come into bearing. With intensive cultivation fruits may be grown in the higher altitudes without irrigation, but with the application of small quantities of water a greater yield is obtained and irrigation is generally conceded to be necessary and beneficial. A branch line of the Southern Pacific Railroad connects Placerville with Sacramento. Other sections of the county are remote from railroad points and agricultural development will be slow until transportation facilities are afforded.

SOILS

The soils of the El Dorado foothill belt vary considerably and are derived from a wide range of rocks. A belt of upturned slates ranging from 1 to 3 miles wide begins south of Cosumnes River and extends northward, including the country around Placerville with an elevation of about 1800 feet, Garden Valley with an elevation of 1900 feet, and Georgetown with an elevation of 2200 feet. The soils are yellowish-brown to yellowish-gray clay loams and loams. In places the color is quite red, due to the influence of wash from the adjoining redder amphibolite and diabase soils. Slate frequently outcrops at the surface but the soil varies from 1 foot to 6 or more feet deep. The soils are friable, easily tilled, productive, and well adapted to fruit culture. They are well drained and free from alkali. No hardpan is present and only in occasional places is blasting necessary for fruit tree planting. Beginning at Diamond Springs and extending northwest beyond Magnolia there is a belt of light reddish to grayish sandy loams and loams derived from granitic material. This belt covers about 30 square miles and varies in elevation from 800 to about 1500 feet. Diamond Springs, Granite Hill, Coloma, and Lotus are the main towns located in this group of soils. The light texture of these soils makes tillage easy and their more rapid absorption of heat causes fruit grown on them to mature earlier than on the heavier soils. The soils range in depth from 2 to more than 6 feet. They are friable, absorb moisture readily, and are capable of growing a wide range of cover crops. They are well drained and contain no alkali. No hardpan is present. Water is necessary during summer for the best returns.

To the west of Placerville, extending down to the valley floor, is a series of formations, chief among which are schists, diabase, and gabbordiorites. These rocks vary considerably in hardness and give rise to deep red clay loams and loams. The elevation of this belt ranges from about 300 to 2000 feet. Latrobe, El Dorado, Shingle Springs, and Clarksville are the principal towns. This belt of soils covers about 300 square miles, about two-thirds of which is suitable for agriculture. The soils vary greatly in depth and in many places are too shallow for fruits without blasting. Drainage is good to excessive in many places and no alkali nor overflow occurs. Much of the soil is from 2 to 6 feet deep and is capable of an intensive agriculture when water and transportation are obtained. Most of these soils are now used for pasturage. Part of this area is somewhat rocky and gravelly and covered with brush. Wherever the rocks are upturned at a high angle and are schistose or slaty in character, tree roots frequently penetrate downward into the crevices and seams many feet. In such places, blasting and filling the bowl formed with fresh soil has proved very successful in fruit culture. Where the underlying rocks are massive this practice is not advisable.

IRRIGATION

Water for irrigation is supplied by three principal systems which were built for mining purposes. These old mining ditches are being enlarged and improved, storage reservoirs are being constructed, and a new development is taking place in the utilization of water for power and irrigation. The cost of water to irrigators is 20 cents per miner's inch per 24 hours. Assuming a depth of 1½ feet per acre applied to orchards during the season, the cost would be $6 per acre.

The Sierra Water Supply Company succeeded to the rights and properties of the El Dorado Water and Deep Gravel Mining Company. Water is diverted from South Fork of American River 31 miles above Placerville and distributed in several ditches to Granite Hill, Camino, and Diamond Springs. About 1000 acres are reported under irrigation.

The Crawford Ditch System, sometimes known as the Diamond Ridge Ditch, was built for mining purposes and is still chiefly used for mining. It diverts water from North Fork of Cosumnes River at Steeley's Fork and is added to from Camp Creek, Clear Creek, Squaw Hollow, and other creeks which it crosses. About 500 acres are irrigated in the vicinity of Diamond Springs, El Dorado, and Shingle Springs. This system comprises about 80 miles of main ditches and

laterals and covers an extensive territory that will eventually be brought under irrigation.

The Truckee River General Electric Company has acquired the ditches of the Loon Lake Water and Power Company, which supplies water to the Georgetown divide. Water is diverted from Gurley and Pilot creeks. One branch of the system extends westerly to Cool and another carries water to Garden Valley and Kelsey. About 1500 acres are reported under irrigation.

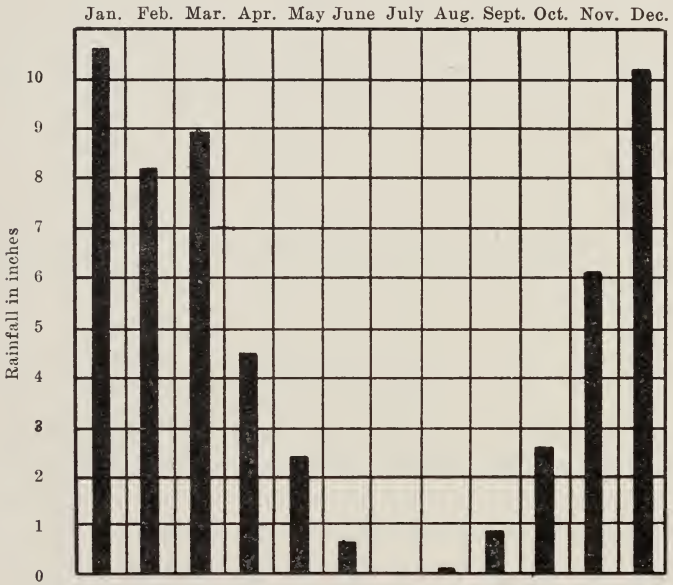

Fig. 26.—Mean monthly rainfall at Nevada City, Nevada County, 1865–1913

NEVADA COUNTY

Nevada County lies north of Placer County and is separated from it by South Yuba and Bear Rivers. Middle Yuba bounds the County on the north. These rivers furnish the water supply for mining and irrigation. Nevada County is widely known for its production of gold and its quartz mines still produce over $2,000,000 annually. The mean annual rainfall at Nevada City, elevation 2580 feet, as shown by the record from 1865 to 1913, inclusive, is 55.32 inches. Figure 26 shows the uneven distribution of the rainfall and it will be seen that during the months of June, July, August, and September there is a

season of drought. On account of the large annual rainfall, the need of irrigation is sometimes questioned, the fact being lost sight of that practically none of the rain falls during the fruiting season. The shallower soils are soon robbed of moisture by the high summer temperatures through evaporation. The benefits of irrigation in this section are, however, becoming more generally recognized and the use of water will become greater as agriculture is more generally practiced.

The Nevada County foothills are located in the western fourth of the county and range in elevation from about 500 to 3000 feet with a rainfall varying from about 24 inches at the lowest altitude to about 56 inches at the highest. About one-third of this area is suitable for agriculture, but the greater part of this has no railroad transportation.

The topography of Nevada County is mountainous and broken and consists of a series of small, narrow valleys, such as Penn and Pleasant valleys, and irregular areas of rounded hills, moderate slopes, and ridges. Grass Valley and Nevada City are the principal centers and are connected by an electric railroad in addition to the steam railway. Other towns are North San Juan, French Corral, Spenceville, and Chicago Park. The rocks in the northeast half of this belt are mainly granodiorites which give rise to light red and grayish-brown sandy loams and loams from 2 to 6 feet deep. The other half is underlain principally by diabase which has produced red clay loams and loams which average from 2 to 4 feet deep. The soils of the latter group are somewhat more durable than the granitic soils but do not mature their fruit quite so early. The soils are usually several feet deep and respond to the same cultural methods recommended for such soils in El Dorado County. They are well-drained and free from overflow and alkali.

The report of the Horticultural Commissioner for Nevada County shows over 80,000 fruit trees in the Nevada County agricultural belt, not including vines, which number more than 60,000. Pears, peaches, apples, and plums, in order named, lead. The quality and coloring of fruit in this belt, like that grown in the other foothill counties, rank very high.

Clean culture in generally practiced except where water is plentiful and then the orchard is tilled only once a year. Hoed crops grown between the rows greatly reduce the cost of bringing the orchard into bearing. Cover crops have proven very successful on these soils for fruit culture. Pears, besides being planted in areas of good drainage, are also successfully grown in valleys where moisture content is too great for other fruits.

The principal irrigation development of Nevada County is in the western portion. The Excelsior Water and Mining Company supplies water for irrigation in Penn and Pleasant valleys and around Smartsville. The main canals and laterals of the irrigation system are practically the same as were used 40 years ago for mining operations. The chief crops irrigated are alfalfa, wild grasses, and deciduous fruits. The Nevada County Narrow Gauge Railway affords the only means of railroad transportation and connects Nevada City with Colfax on the main line of the Southern Pacific Railroad.

AMADOR COUNTY

Amador County is rich in mineral deposits and but little attention has been given to agriculture, aside from the growing of grain. The famous Mother Lode traverses the County from northwest to southeast, on which numerous quartz mines are located.

From about the 500-foot contour upwards, the soils of Amador County are derived mainly from slates, with intervening belts of diabase and schist. They are red to yellowish loams and clay loams and are friable for several feet in depth. Where the soils are less than 3 feet deep blasting is advisable for fruit culture.

On the steeper slopes and ridges the soils are generally more or less gravelly and seldom extend to a depth greater than 2 feet. The loams and gravelly loams predominate in such places and rock outcrop is not infrequent.

The clay loams are similar in color to the loams, but are usually deeper, contain less gravel, and are more retentive of moisture. They occupy the more gentle slopes and small valleys, and are more difficult to till.

Both types are well drained, free from alkali, and are not affected by overflow at any time. Torrential rains sometimes cause gullies to form over the surface, but this can generally be avoided by proper methods of tillage. The soils are relatively low in humus and respond well to applications of organic matter. The bedrock is upturned at a high angle and may be blasted successfully for fruits where necessary.

Below the 500-foot contour, from Ione westward, the soils are derived mainly from gray clays and sandstone. The soils resting on this formation correspond closely in value and in suitability to crops to the soils of the lower foothills in Calaveras and Stanislaus counties. They range in texture from loams to clay loams.

The loams occupy the higher slopes, are gray to grayish-brown in color, and average about 2 feet deep. They are deficient in humus and rest on gray cemented beds which in many places are many feet thick. Local areas of gravel are present, but they are not extensive enough to seriously interfere with tillage or crop growth.

The clay loams are of the same color as the loams but are generally deeper and occupy the more gentle slopes and small valleys. At 2 to 6 feet deep they rest on gray cemented beds which are usually too thick to be blasted successfully.

These two types are low in humus, are generally known as shallow, droughty soils, and are of little value for crops without water. They support a sparse growth of brush and grass and generally require some leveling for fruits and alfalfa. Drainage is good and alkali rarely occurs except in small basin-like depressions. Organic matter, irrigation, and transportation are the controlling factors of agriculture in this belt.

Jackson, Martell, Sutter Creek, Amador, Plymouth, Ione, and Buena Vista are the principal towns in the foothill belt of this county. Ione and Jackson valleys are fertile and capable of a high state of cultivation. Intensive development has been retarded by large holdings, one grant controlling 35,000 acres. Present irrigation is confined to small tracts of from 2 to 5 acres and there are only a few irrigated tracts over 100 acres in extent. The county is well covered with ditches which supply water for mining and the generation of power. Chief among these are canals owned by the Pacific Gas and Electric Company, the Consolidated Amador and Volcanic Hydraulic and Gold Mining Land Company, and Hayward, Hobart, and Lane. It is thought that eventually there will be reorganization and readjustment of these systems which will result in a larger quantity of water being made available for irrigation. Martell and Ione are on a branch railroad leading to Galt, a station on the main line of the Southern Pacific Railroad.

CALAVERAS COUNTY

Calaveras lies south of Amador County and is separated from it by Mokelumne River. The Stanislaus River forms its southern boundary. Agricultural pursuits in this county, as in Amador, have been neglected owing to the mining and timber resources. The western and northwestern portions are mainly devoted to raising wheat and barley, both for grain and hay. The hills and mountains are extensively

used during the summer months for the grazing of sheep and cattle from the plains of the San Joaquin. Irrigation is confined to vegetable gardens and small orchards and water is taken from old mining ditches. Wherever attention has been given to fruit raising, good results have been obtained. Transportation is needed to foster the fruit industry.

Nearly all of the foothill area of Calaveras County suitable for agriculture lies below the 2000-foot contour. Angels Camp, San Andreas, and Mokelumne Hill are the principal towns above 1500 feet, and Valley Springs, Wallace, Jenny Lind, Milton, and Copperopolis are the main towns from the 1000-foot elevation to the base of the foothills. Several small valleys, chief among which is Salt Springs Valley northwest of Copperopolis, are located in the area.

With the exception of a small area of granodiorite at Mokelumne Hill and one east of San Andreas, the main rocks giving rise to the soils in this belt are schists, slates, and diabase. The soils derived from these rocks are reddish clay loams and loams and range in depth from 1 foot to 6 feet. They are not difficult to till, are friable, and are deficient in humus. Drainage is good and no alkali is present. The soils on the steeper hillsides and ridges are shallow and sometimes gravelly, but on the more gently sloping areas are deeper and better suited to crops. From the 300-foot to the 500-foot levels the soils are mainly gray loams derived from underlying beds of gray clays and sandstones. These soils are usually shallow and poorly adapted to agriculture. They range in depth from 1 foot to 6 feet, but average about 2 feet deep. They are friable, easily tilled, well drained, free from alkali, and low in humus. Peaches, apricots, plums, grapes, truck, grain, and alfalfa do well if water is provided. Some leveling is necessary for crops. In small valleys and on gentle slopes, however, the soils are deeper and when supplied with water produce good crops.

Dry-farm grain and some alfalfa are grown in the lower and more level valleys. The soils generally are easily tilled, friable and require organic matter for best yields. Irrigation is essential for fruit culture but the amount necessary decreases with higher elevations. Water for irrigation, organic matter, and transportation are the governing factors of successful agriculture on the soils of this county. Branch railroads connect Wallace, Valley Springs, and Milton with outside points.

TUOLUMNE COUNTY

Tuolumne County occupies a central position in the Sierra foothill belt. Tuolumne and Stanislaus rivers with their tributaries divide the county into a series of irregular plateaus, ridges, and small valleys. Table Mountain forms a striking feature of the topography of this section. Its summit is covered by a heavy flow of basaltic lava of a dark color and dense texture. Owing to the more important industries of mining and lumbering, there has been no real impetus to agricultural development. Farming is limited to the growing of grain and hay. The early miners set out a number of small orchards for the purpose of supplying fruit for domestic use. Where the trees received sufficient care fruit of good quality was successfully grown.

The foothills of Tuolumne County suitable for agriculture embrace the region around Sonora, Tuolumne, Columbia, Jamestown, Jacksonville, Groveland, and Big Oak, and also a number of small isolated areas. This belt embraces an area of about 125 square miles and varies in elevation from about 1000 to 3000 feet.

The soils of this belt vary considerably, due to the varying kinds of rocks giving rise to them. An extensive area of granodiorite begins a short distance east of Sonora and gives rise to light red sandy loams and loams. These soils vary in depth from 1 foot to 6 feet or more, are fertile, warm quickly in springtime, and mature their fruit early. Rock outcrop occurs locally but the soil covering is usually of sufficient depth for deep rooted crops. Drainage is good and no alkali is present. Tillage is not difficult except on the steep slopes where gravelly areas occur. The heavier soils from the slates and diabase are usually much redder than those from granodiorite and vary greatly in depth. They are well drained and easily prepared for crops except where covered with brush and timber. Southern and western slopes are generally droughty. These soils rank among the best for fruit culture.

The apple industry ranks first in this region and is receiving considerable attention. The success of the fruit industry must depend largely upon irrigation. The average annual precipitation at Sonora, based on a record of 26 years, is 35.79 inches, almost all of which falls during the winter months. Owing to the shallow soils, steep slopes and consequent excessive drainage, in many places very little of the moisture in retained in the soil for the dry season. Water for irrigation is supplied by the Sierra and San Francisco Power Company which has succeeded to the rights and properties of the Tuolumne

Water Company. The ditches are old mining ditches and have an aggregate length of 126 miles, 86 miles of which are now used for irrigation and power purposes. Water is diverted from South Fork of Stanislaus River and delivered to lands in the vicinity of Sonora, Columbia, Jamestown, Soulsbyville, and Tuolumne. The charge for water in 12½ cents per miner's inch per 24 hours run. Assuming an average use of about 2 acre-feet per acre, the cost will be $5 per acre per annum. The irrigated area comprises about 1200 acres, a considerable portion of which is given over to the production of apples in the higher altitudes, while the remainder is devoted to small alfalfa patches and gardens.

Transportation is afforded by the Sierra Railway. Good tillage, the liberal use of green manure crops, proper irrigation, and an effective selling organization appear to be the main factors essential to successful commercial fruit growing in the region.

MARIPOSA COUNTY

Mariposa County lies entirely within the Sierra foothills and mountains. Merced River, which has its head waters in Yosemite National Park, is the only stream of importance traversing the county, its waters being used for irrigation on the plains near Merced. This river, together with Bear, Mariposa, and Chowchilla creeks, divides the county so that it consists of numerous irregular plateaus, long ridges, and narrow valleys. The area south of Bear Creek is, in general, treeless. In the vicinity of Mariposa, between elevations of 1500 and 2500 feet, the hills and ravines are covered with a thick growth of chaparral and manzanita and a scattered growth of white oak and bull pine. In higher altitudes there are valuable forests of yellow and sugar pine and giant sequoias of the Mariposa Big Tree Grove.

About 275 square miles of land capable of cultivation lies in the southwestern part of the county, chiefly south and west of Lewis and around Hornitos, Mariposa, Bootjack, and Jerseydale, and in Bear Valley. There are also about 20 square miles in the region of Coulterville north of Merced River and a number of other small valleys and coves, capable of an intensive agriculture. Development of the foothill belt here has been slow, however, on account of poor transportation and scarcity of available water for irrigation. There are many small storage reservoir sites along the various creeks and a

number of locations for larger ones which, when utilized, will cover much of the tillable land.

The foothill belt of this country varies in elevation from 400 feet in the western part of the county to about 3000 feet a few miles east of Bootjack. The rainfall is about the same as at similar elevations in Tuolumne County to the north.

The soils from Lewis westward consist of yellowish-gray, red, and reddish-brown loams and clay loams. They are friable, easily tilled, retentive of moisture, productive, and usually of sufficient depth for the growing of all crops. Small areas of gravel are present locally. The clay loams have the same range in depth as the loams, but are usually rolling and retain water a little better. Both types are well drained, free from alkali, and not affected by overflows.

Very little or no brush occurs on this part of the foothills, and the land is easily cleared and prepared for crops. Some adobe occurs on the lower slopes. The granitic soils are reddish to grayish sandy loams and loams varying considerably in depth. The soils from the other rocks, except the slates, are red clay loams and loams. They are not difficult to till, are usually of good depth, and when supplied with water give good yields.

About four-fifths of the tillable area of this part of the foothill belt lies west of Mariposa. The soils and range of crops possible in Mariposa County are similar to those in Tuolumne County. Water is required for most crops, except grain and grapes, for the best results. This can be supplied by storage reservoirs only, as the streams are intermittent in character and there is no rainfall during summer. Irrigation is confined to a few small gardens and fruit farms, which depend upon springs and wells for their water supply. About 430 acres were irrigated in 1913. With the improved transportation, an increased water supply, and good farm practice this county is capable of much development along agricultural lines.

MADERA, MERCED, AND STANISLAUS COUNTIES

The foothill district of Stanislaus, Merced, and Madera counties is the lower extension of the western Sierra slopes where they merge into the plains below. The belt averages about 5 miles wide and is nearly 100 miles long. The elevation ranges from about 200 to 500 feet, and the rainfall varies from about 12 inches in the southern part to about 17 inches at La Grange, midway in the belt, and about 20 inches in the northern end.

The topography of this section of the foothill belt consists of low hills, slopes, and small valleys. In places a hog-wallow surface occurs which requires leveling before irrigation can be practiced. The soils[10] are mainly reddish-brown to gray or brown sandy loams, loams and clay loams, with small areas of dark colored adobe on some of the slopes.

The reddish-brown to brown soils have a hog-wallow surface. They vary in depth from 1 foot to 4 feet and rest upon a dense hardpan which is nearly always present. Below the hardpan the soil is usually friable and blasting usually gives excellent results. Occasionally gray semi-cemented beds occur beneath the hardpan, and in such places blasting frequently does more harm than good.

The gray loams and clay loams near the margin of the plains are the weathered products of deep semi-cemented beds of clay and volcanic material. These soils are usually shallow. Small amounts of rounded to angular gravel are present in places over this part of the foothills. The higher-lying areas are residual and have no hardpan. They are usually not difficult to till and are well drained.

Where water is available, peaches, plums, figs, grapes, berries, truck, and some other deciduous fruits are grown. Water is the controlling factor for intensive crops in this belt and humus is needed for the best returns. Nearly all of the area is used for pasture and dry farmed to grain at the present time. Irrigation is confined to a rather narrow belt along the streams passing through this belt of soils. Gravity canals are the only source of water to date, but indications show that pumping from wells may become an important feature in places in the future. Small storage reservoirs will also have an important place.

KERN COUNTY CITRUS BELT

The foothill area of Kern County comprises a belt of elevated land lying east of Famoso and Bakersfield and extending southerly to the junction of the Sierra Nevada with the Tehachapi Mountains. The elevation of this belt ranges from about 500 to 1200 feet and the average annual rainfall is about 5 inches. The climate is very favorable for the early maturity of citrus fruits and damage from freezes seldom occurs.

[10] For fuller description of soils of these counties see U. S. Dept. Agr., Bureau of Soils, Soil Surveys of Madera, Merced, and Modesto-Turlock areas.

In part the area may be considered as the lower extension of the Sierra Nevada, and in part as a gradually-sloping mesa merging into the more level valley plains to the west. This belt of territory is from 6 to 10 miles wide and about 60 miles long. The soils consist principally of sandy loams and loams. Local areas of lighter or heavier material occur, but they are small and of minor importance agriculturally. The soil is grayish-brown to brown or light reddish-brown in color, is generally low in humus, and is easily tilled. A noticeable amount of clay is present, making the soil sticky when wet. The clay content of the subsoil frequently increases to a depth of about 6 feet and in some places approaches a heavy loam to clay loam. The red color of the surface soil is usually intensified in the subsoil but in many places the soil is uniform in color and texture to 6 feet or more deep. The substratum below 6 feet usually becomes lighter in texture and resembles the surface generally. The sand particles are generally coarse and gritty and are mainly quartz. Some gravel is occasionally present in the soil and subsoil but it is confined to small irregular areas and is not a serious obstruction to tillage. Gravelly areas are more pronounced on the higher mesas.

The soils of the mesas, lower ridges, and slopes consist mainly of old alluvial and sedimentary material, and that on the higher foothills is mostly residual from granites and from metamorphic and sedimentary rocks. A small amount of colluvial material occurs on the steeper slopes over the entire belt.

The greatest deficiency of the soils in this belt of territory is in humus, and water is the controlling factor of plant growth. A wide range of green manure crops thrive, however, which make it possible to supply organic matter. Besides improving the texture, organic matter will greatly increase the water-holding capacity of the soil. No alkali or hardpan is present on the higher slopes, ridges, and mesas, but bare spots showing an excess of salts begin to appear and become more numerous as the valley trough is approached.

Where water is available in this belt, indications point to the possibility of an extensive citrus development. At the present time, the lack of irrigation development is due to an insufficient gravity water supply. The principal irrigation development centers around Edison, 8 miles east of Bakersfield, where 600 acres have been planted to oranges in two sub-divisions. Water is obtained by pumping from wells, and mutual water companies have been organized for the purpose of supplying water to each sub-division, and the charges for water are based upon the actual cost of operation and maintenance. On one sub-division, each 10-acre grove is given a run of 60 miner's inches of

water for 24 hours each month during the irrigation season, at a cost of 16⅔ cents per inch, which amounts to $1 per acre per irrigation. On another tract the charge is 25 cents per inch, which amounts to $1.50 per acre per irrigation. Water is usually applied five to seven times during the season.

The wells at Edison are 10 inches in diameter and from 350 to 500 feet deep, the lift varying from 130 to 230 feet. The pumping installations consist of electric motor and deep-well pumps, the latter yielding from 40 to 100 miner's inches of water.

SUMMARY

Approximately 8000 square miles or 5 per cent of the total land surface of California is included in the foothills along the western slope of the Sierra Nevada. The arable portion is estimated at ⅛ to ⅗ of the total area, but only about 70,000 acres are now under irrigation.

Water is available for irrigation from numerous streams of the Sierra and only storage works are needed to conserve large volumes now running to waste to make this belt of elevated land one of the most important agricultural districts in California. In many places ditches are already provided which were constructed at an enormous cost for mining operations. Irrigation provides a new way for the continued uses of these ditches coupled with the use of water for the generation of power.

The foothills have a most valuable asset in topographical features and climate which assure the early ripening of fruits. A marked variation in elevation, rainfall, and temperature makes possible a wide range of profitable crops. The soils are well adapted to the growing of fruit. Within the thermal belt the orange and olive industries are established on a firm basis. The oranges from the north are usually picked and marketed before free movement begins in the south.

Deciduous fruits have long proved profitable and the shipments of fresh or "green" fruits from the northern counties have added materially to the wealth of the State. The apple finds a suitable home and flourishes in the higher elevations of the foothills.

The greatest handicaps in most districts are the lack of proper transportation facilities and adequate water supplies. These will undoubtedly be provided in increasing measure as more people become familiar with and take advantage of the natural resources of this old, romantic, yet in an agricultural sense, new territory of California.

STATION PUBLICATIONS AVAILABLE FOR DISTRIBUTION

REPORTS

1897. Resistant Vines, their Selection, Adaptation, and Grafting. Appendix to Viticultural Report for 1896.
1902. Report of the Agricultural Experiment Station for 1898–1901.
1903. Report of the Agricultural Experiment Station for 1901–03.
1904. Twenty-second Report of the Agricultural Experiment Station for 1903–04.
1914. Report of the College of Agriculture and the Agricultural Experiment Station, July, 1913–June, 1914.

BULLETINS

No.
168. Observations on Some Vine Diseases in Sonoma County.
169. Tolerance of the Sugar Beet for Alkali.
170. Studies in Grasshopper Control.
174. A New Wine-Cooling Machine.
177. A New Method of Making Dry Red Wine.
178. Mosquito Control.
182. Analysis of Paris Green and Lead Arsenate. Proposed Insecticide Law.
183. The California Tussock-Moth.
184. Report of the Plant Pathologist to July 1, 1906.
185. Report of Progress in Cereal Investigations.
195. The California Grape Root-worm.
197. Grape Culture in California; Improved Methods of Wine-making; Yeast from California Grapes.
198. The Grape Leaf-Hopper.
203. Report of the Plant Pathologist to July 1, 1909.
207. The Control of the Argentine Ant.
208. The Late Blight of Celery.
211. How to Increase the Yield of Wheat in California.
212. California White Wheats.
213. The Principles of Wine-making.
216. A Progress Report upon Soil and Climatic Factors Influencing the Composition of Wheat.
225. Tolerance of Eucalyptus for Alkali.
227. Grape Vinegar.
230. Enological Investigations.
234. Red Spiders and Mites of Citrus Trees.
240. Commercial Fertilizers.
241. Vine Pruning in California. Part I.
242. Humus in California Soils.
243. The Intradermal Test for Tuberculosis in Cattle and Hogs.
244. Utilization of Waste Oranges.
246. Vine Pruning in California. Part II.
248. The Economic Value of Pacific Coast Kelps.
249. Stock Poisoning Plants of California.
250. The Loquat.
251. Utilization of the Nitrogen and Organic Matter in Septic and Imhoff Tank Sludges.
252. Deterioration of Lumber.

CIRCULARS

No.
65. The California Insecticide Law.
68. The Prevention of Hog Cholera.
69. The Extermination of Morning-Glory.
70. Observations on the Status of Corn Growing in California.
76. Hot Room Callusing.
79. List of Insecticide Dealers
80. Boys' and Girls' Clubs.
82. The Common Ground Squirrels of California.
83. Potato Growing Clubs.
84. Mushrooms and Toadstools.
87. Alfalfa.
88. Advantages to the Breeder in Testing his Pure-bred Cows for the Register of Merit.
91. Disinfection on the Farm.
92. Infectious Abortion and Sterility in Cows.
100. Pruning Frosted Citrus Trees.
101. Codling Moth Control in the Sacramento Valley.
102. The Woolly Aphis.
106. Directions for using Anti-Hog-Cholera Serum.
107. Spraying Walnut Trees for Blight and Aphis Control.
108. Grape Juice.
109. Community or Local Extension Work by the High School Agricultural Department.
110. Green Manuring in California.
111. The Use of Lime and Gypsum on California Soils.

No.
113. Correspondence Courses in Agriculture.
114. Increasing the Duty of Water.
115. Grafting Vinifera Vineyards.
116. Silk Worm Experiments.
117. The Selection and Cost of a Small Pumping Plant.
118. The County Farm Bureau.
119. Winery Directions.
120. Potato Growing in the San Joaquin and Sacramento Deltas of California.

No.
121. Some Things the Prospective Settler Should Know.
122. The Management of Strawberry Soils in Pajaro Valley.
123. Fundamental Principles of Co-operation in Agriculture.
124. Alfalfa Silage for Fattening Steers.
125. Aphids on Grain and Cantaloupes.
126. Spraying for the Grape Leaf Hopper.
127. House Fumigation.
128. Insecticide Formulas.

Relief map of California showing in solid black the general location of the arable areas in the Sierra foothills